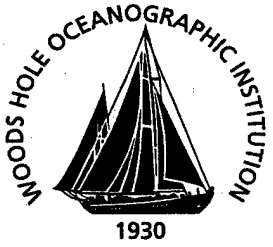
WHOI-00-02

Woods Hole Oceanographic Institution



Whale Call Data for the North Pacific November 1995 through July 1999 Occurrence of Calling Whales and Source Locations from SOSUS and Other Acoustic Systems

by

William A. Watkins
Joseph E. George
Mary Ann Daher
Kristina Mullin
Darel L. Martin
Scott H. Haga
Nancy A. DiMarzio

February 2000

Technical Report

Funding was provided by the Office Naval Research under Grant No. N00014-96-1-1130, SERDP and CNO N45.

WHOI-00-02

Whale Call Data for the North Pacific November 1995 through July 1999 Occurrence of Calling Whales and Source Locations from SOSUS and Other Acoustic Systems

by

William A. Watkins
Joseph E. George
Mary Ann Daher
Kristina Mullin
Darel L. Martin
Scott H. Haga
Nancy A. DiMarzio

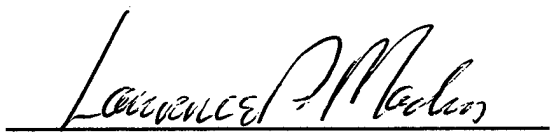
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

February 2000

Technical Report

Funding was provided by the Office Naval Research under Grant No. N00014-96-1-1130, SERDP and CNO N45.

Approved for Distribution:



Laurence P. Madin, Chair

Department of Biology

WHALE CALL DATA FOR THE NORTH PACIFIC

NOVEMBER 1995 THROUGH JULY 1999

OCCURRENCE OF CALLING WHALES AND SOURCE LOCATIONS

FROM SOSUS AND OTHER ACOUSTIC SYSTEMS

William A. Watkins, Joseph E. George, Mary Ann Daher,

Kristina Mullin, Darel L. Martin,

Scott H. Haga, and Nancy A. DiMarzio

Woods Hole Oceanographic Institution

Woods Hole, MA 02543

Support via ONR Grant N00014-96-1-1130

with funding from SERDP and CNO N45

CONTENTS

ABSTRACT

Calls of blue whales (Balaenoptera musculus), fin whales (Balaenoptera physalus), and humpback whales (Megaptera novaeangliae) were identified in the data from U.S. Navy Sound Surveillance System (SOSUS) and other hydrophone arrays. These data on calling whales from November 1995 through July 1999 have been listed here for four offshore, deep-water Regions along continental margins of the North and Northeast Pacific. The occurrence of calling whales was monitored during two-day periods each week. Call data recorded from each array identified species, call occurrence, variation, received beam, and relative numbers of calling whales. This allowed assessment of seasonal distribution of calls for the different species, and provided locations for sources received at multiple arrays. Blue whale tonal sounds were distributed widely, received most in the NW Region, with a peak in occurrence in the fall. Fin whale "20-Hz" repetitive pulse sequences were received from whales grouped in local areas in all Regions, with a peak in occurrence in midwinter. Humpback songs were received from December through May particularly in the SE Region. The offshore listening systems allowed basin-wide monitoring of the seasonal distribution of these calling whales.

INTRODUCTION

Since 1958, beginning with early U.S. Navy hydrophone array installations, such as off Nantucket Is, MA, researchers from the Woods Hole Oceanographic Institution have used data from such arrays to observe and follow variations in calling by the different whale species. The level of Navy classification of information from these facilities prevented direct application of such data obtained from these arrays to the studies of whales at sea. However, it was possible to relate the occurrence of certain sounds to the presence of whales of particular species, and to confirm that the calling patterns observed from ships close to the whales could also be recognized on the standard Navy acoustic displays of their array data. Periodically, concentrations of the different whale species could be located in the areas indicated by the Navy arrays so the details of the whale acoustic behaviors could be studied from shipboard. Many of the early identifications of whale call repertoires, in fact, developed from the integration of observations of the sound patterns on the Navy acoustic displays with our ship-based studies of the whales at sea. These experiences provided confidence that the calls received by the Navy acoustic systems were indeed those of particular species of whales.

Therefore, as such data became available in recent years, not only from military but other systems as well, the Navy came to our aid, and programs were initiated to help Navy analysts identify biological noises. With the retirement from the Navy of some of these expert analysts, we began a systematic program, with their help, to monitor whale calls across the North Pacific Region. The whale call monitoring program was formally organized through SPAWAR (Dr. Dennis Conlon) in 1995, and the careful collection of whale call data has continued uninterrupted since November 1995.

Our previous experience with SOSUS and with the Navy acoustic processing systems had demonstrated that we could use unmodified Navy and other existing acoustic systems to recognize reliably particular whale call patterns from several whale species. It was important to impact Navy facilities as little as possible, and so organization of the data at Woods Hole was planned. A system was required that would allow monitoring of the acoustic data by analysts experienced in both recognition of whale calls and in operation of the Navy analytic systems. The call data needed to be recorded in unclass format, transferred without error to Woods Hole for organization into appropriate

database systems, and retrieved as needed for analysis of the seasonal occurrence of calling whales. These analyses could then be distributed as timely, updated information on the presence of calling whales in the North Pacific Regions.

These tasks have been accomplished. A very simple monitoring protocol and data recording techniques evolved which allowed appropriate handling of the call data and permitted wide flexibility in comparisons and analyses of the variations in distribution, movements, seasonality, and call repertoires of the different species.

METHODS

The acoustic data from offshore SOSUS and other hydrophone arrays in the North Pacific were monitored beginning in November 1995, and recognized whale calls were recorded and analyzed to describe their distribution and seasonality. Locations for many of the Navy hydrophone systems remain protected, as are their characteristics and associated data processing. The hydrophone arrays that were monitored were bottom mounted with a variety of sensor configurations. To provide comparable information from Navy and all other arrays, regardless of their composition, the beam-formed array data were interpolated to provide the equivalent of 40 line array beams for each array. Array orientations were not considered for these analyses. The occurrence of calling by whales was assessed from the beam-formed spectrographic data from ten arrays selected to provide representative coverage for four offshore Regions along the continental margins of the North Pacific. These offshore Regions were labeled NW, NC, NE, and SE, divided at increments of 30^{o} Longitude by 15^{o} Latitude (see map page 25). Some north-south detail was provided by the use of two or three arrays located at different latitudes within these Regions. Arrays in each Region were labeled from the north

(SE1 north of SE2 in SE Region, etc.). There was little overlap between Regions and even between arrays within Regions for the usual calling occurrence data. Two arrays were monitored in each of the NW and NC Regions and three (potentially one-third more observations) in the NE and SE Regions.

Arrays were monitored by analysts with extensive experience working with these Navy and other acoustic systems, as well as with the spectrographic display of beam-formed analyses of the whale calls. .Call identifications were reviewed regularly by WHOI researchers with 10 to 40 years experience with such sounds. The occurrence of calling by the different whale species was ascertained by visual scrutiny of spectrographic analyses of the acoustic data from all beams for each of the ten arrays. The data from these arrays were systematically examined over the same period during two, usually consecutive, 16-hour days every week, centered on 1200 hours GMT, spanning both daylight and darkness in each Region. Calls of one to five whales of the same species distinguished on the same beam generally within a period of about four hours were considered one occurrence, and no new occurrence was logged for that day unless it was obvious that another set of calls had begun from a markedly different distance (sharp difference in level

and acoustic pattern). One dominant beam displaying the calls was identified for each occurrence. During analysis, a convenient interval for examining the data has been about four hours, and so often this period has been used as a practical minimum interval between new call occurrences. Call sequences often continued over much of the day, and therefore, were recorded as one occurrence. If similar call sequences were present on the same array beam on the second day, they were recorded as another occurrence. When there were too many whales (six or more, usually many more) of apparently the same species to separate, this concentrated calling noise which normally lasted for most of the day was recorded as one "J" occurrence (such noise was traditionally called "Jezz" by Navy analysts). When call sequences with acoustic patterns and spectra identifiable to specific call patterns of blue, fin, and humpback whales were noted, these were logged as a single call occurrence for each species. Background calling from other whales of the same species was not recorded so as to confine identification of calls to the most easily defined, closer calling.

Thus, the number of occurrences of whale calling did not provide a count of calling individuals or of the number of calls. Instead, they indicated the number of new call sequences within a period of about four hours or longer from

each species. These were identified on any of 40 beams for each of the different arrays in the four Regions of interest during the two 16-hour per day sampling periods. These data provided comparative measures of calling by each species and of the variations in calling with season and location.

Supplemented by data from a variety of other fixed and mobile hydrophone systems, locations for calling whales also could be assessed. To accomplish this, the same call had to be verified with detailed spectrograms of call sequences superimposed on two or more arrays. Triangulation from the directions for sound reception from the different hydrophone systems provided estimates of sound source positions. Multiple positions for successive call sequences from individual whales allowed refinement of their locations and tracking of their movements. The location of areas with concentrated calling apparently from numbers of whales also could be observed to change over time as local groups of calling whales moved, over days or weeks.

WHALE CALLS

Whale calls in these acoustic displays that were most recognizable with little confusion from other sounds had prominent low frequencies (propagating well) and were repetitive with tonal characteristics (distinguishable from ambient noise). Less repetitive and transient sounds readily masked by noise were not a part of these observations. The whale calling data analyzed here included species identification, occurrence of calling, and received beam without consideration of array orientation.

Call sequences from blue whales (Balaenoptera musculus) and fin whales (Balaenoptera physalus), and songs from humpback whales (Megaptera novaeangliae) were clearly identified on spectrographic displays of the beam-formed acoustic data from the hydrophone arrays. The occurrence of calls from each species was different in the four regions, varying with season and changing patterns of calling. Call occurrence for the different species generally was consistent between years, with similar patterns of calling recorded from similar directions (comparable array beams) during corresponding seasons.

The blue whale call sequences that were identified were their long series of repetitive, downswept tonal calls with

fundamental frequencies usually below 20 Hz and several harmonics, repeated variably at 3 to 10 min intervals, often over several hours. Shorter calls from this species were not consistently separable from noise and so were not a part of these analyses.

The fin whale call sequences that were identified were the repetitive, down-swept "20 Hz" pulse series with most energy near 20 Hz and little harmonic energy. Pulses of about 1 sec each were repeated regularly at rates of a few seconds in characteristic temporal patterns with three or four rests of a few minutes each hour over periods of 16 hours or more. The short sequences and social calls were not as easily separated from noise and so were not a part of these analyses. Fin whale calling analyzed here included call sequences that could be reliably distinguished as coming from individuals (labeled "F") and overlapping concentrations of calls from too many whales in a local area to allow separation (labeled "J"). The J component swamped concurrent calling by individuals, unless they were relatively close to arrays. Combining F and J components provided a more realistic measure of fin whale calling.

Humpback whale song components could be recognized reliably, although only the lower frequencies below a few hundred Hertz were typically received from distant whales.

NUMBERS OF WHALES CALLING

Judgements of the numbers of calling whales represented in these Whidbey data have been based on the experience of the observations to date. A relatively large amount of data and considerable familiarity with the spectral representations of the whale sounds were needed before realistic estimates of numbers of calling whales could be assessed. Doubtless such estimates will be refined as monitoring techniques develop over time and as the amount of data increase.

The estimated counts of calling whales (see page 140) were from assessments of the numbers of overlapping call sequences from different individual whales represented in the data for each calling event. The estimated numbers of calling whales were different on average for each species and varied with each season. They indicated seasonal differences in the numbers of calling whales of each species in each Region. They also were likely to be indicative of differences in whale behaviors with season and locality in the deep waters of the North Pacific. These estimates of numbers of calling whales were considered a beginning step toward quantification of the call data from these pelagic populations, representing the usual patterns of calling individuals noted in these observations of groups of whales.

Reviewing the call data from the arrays in detail allowed an indication of the usual numbers of whales that were involved in the call occurrences that were logged. The assessments were related to the general whale calling seasons. These were offset from the calendar year by one month to match the apparent cycle of whale calling -- Spring (March - May), Summer (June - August), Fall (September - November), and Winter (December - February).

Blue whale calling during their Fall peak season usually was from three to eight or more whales -- the average appeared to be from about five whales for each calling event, often from too many whales to separate. During the Winter as blue whale calling waned, and then during the Summer as it increased again, calling was from one to three whales so we have used 1.5 as the multiplier. During the Spring lowest calling season, only one whale usually was evident during each calling event.

Fin whale calling ("F" calls, distinguishable from individuals) during the peak Winter season was from one to five whales, averaging three calling fin whales per event. During the adjacent Spring and Fall seasons, calling was from one to three whales so a multiplier of 1.5 has been used.

During the Summer period of lowest fin whale calling, only one whale was evident during most calling events. The "J" calls by fin whales, however, regardless of season, were judged to be from six to very many more fin whales, so a multiplier of 6 has been used for all J calling. Combining the F and J calls likely provided a better assessment of the actual numbers of calling fin whales.

Humpback whale songs were evident usually from groups of whales, estimated at three or more individuals, singing during each event, regardless of location or season.

In addition to the individual whales of each species that were calling, of course, there were likely to be many more whales associated with them. Little is known of the numbers of calling individuals within groups of whales, and most such observations have been of inshore populations which may have quite different patterns of activity from the offshore whales. There has been little reliable information about the whales in offshore waters. These acoustic data represent some of the first consistent information that has ever been obtained for the deep-sea whale populations.

THE DATA

The whale call data have been collected in two forms: (1) occurrence of calls, and (2) location of call sources.

Occurrence of Calls -- The call occurrence data (see page 26) provided comparisons of the presence of calls on the different arrays from the different species. Calling was identified for the same time period relative to its presence on each of 40 beams on every array that was monitored. The regular sampling of these data year round over three to four years has allowed assessments of the distribution of calling whales and their seasonal occurrence.

Calls from blue whales (Balaenoptera musculus), fin whales (Balaenoptera physalus), and humpback whales (Megaptera novaeangliae) were clearly identified in spectrographic displays of the beam-formed acoustic data from the hydrophone arrays. The occurrence of whale calls from each species was different in the four Regions, varying with season and changing patterns of calling. Call occurrence generally was consistent between years, often with similar patterns of calling recorded from the same array beams during the same periods of different year. The call occurrence data for blue whales, fin whales and humpback whales from November 1995 through July 1999 have been plotted, beginning on page 26. These graphs compare the call occurrence data by

array and beam for each of the four Regions. The data for each year are compared for the different species.

Note that data for the NW and NC Regions were not available during November 1996 and October 1998.

Locations for Calling whales -- The location of calling whales provided good information on whales whose sounds were sufficiently separated from competing noise to be received well enough to be positively recognized on more than one array. Therefore, call locations could be achieved most when there were few calling whales of that species in the local area, and during periods of peak calling few calls could be separated sufficiently for source localization. Call locations showed the presence of considerable numbers of individual calling whales in all Regions and in all seasons. They also indicated movements of individuals when their calls were sufficiently unique for positive recognitions of sequential sounds. Therefore, the data on call locations were more variable over time and had different periods of peak abundance from the data on call occurrence.

Locations for calling blue whales within the four Regions were plotted relative to the month and season. Consistently, there were few fin whale call locations so these were plots were omitted. The locations for singing humpback whales were plotted by month for the SE Region only to show their strong

seasonal occupation of that area. No songs were heard in August, September and October (see page 146). Comparison of the call location data with the call occurrence data provided the best information on the presence of calling whales in the different Regions.

Track of 52-Hz Whale -- the track of a whale with unique 52-Hz calls is plotted for the 1998-1999 season (see page 156). This sound source has been the only one with this call structure in the entire listening area. We have been tracking this call since 1992, and have not identified the whale species -- perhaps it is a hybrid. The 52-Hz whale has consistently had movements that were somewhat similar to the migrations of many of the blue whales, but the timing of its presence in the area has been more like that of fin whales. The call patterns, however, have not been particularly like either blue or fin whales, although sideband frequencies (harmonic intervals) were compatible with many blue whale calls. The calls have dominant energies near 52-Hz and two or three side bands at intervals of approximately 17.5 Hz, but never any energy at a fundamental frequency. The pattern of call repetition and duration of individual calls as well as the sequence of calls has been highly variable, although the clustering of calls has been characteristic. The clustered calls, their frequency and sideband structure have allowed easy identification.

WHAT HAVE WE LEARNED?

Before these analyses of acoustic data, our knowledge about the presence of whales in the deep waters of the North Pacific was based only on occasional sightings.

Most of the previous whale data were from sightings during summer, usually daylight experiments and surveys. Acoustics had seldom been used for assessments of the presence of whales in these deep waters, although years of ship recordings had identified characteristic sounds from the different species. Few blue whales were thought to exist away from shelf waters where some were seen occasionally feeding, and these were considered likely to migrate to southern waters during winter. It was thought that there were not many fin whales in deep water, and they, too, were considered to migrate to southerly waters in winter. Humpbacks feeding in near-shore waters of Alaska were thought to move to calving areas, such as Hawaii, and usually to begin to sing when they reached those waters.

The data from SOSUS and other acoustic systems immediately corrected many of these ideas.

The new information was a surprise:

-- Whales heard by these systems were calling night and day in all the deep-water Regions and in all seasons.

-- Calling whales could be located and tracked over relatively long distances (without any whale disturbance).

-- Calling whales of the each species were distributed differently in each season, and call patterns within species could be correlated with shifting components of the populations. The ocean-wide monitoring provided a truly comprehensive view of whale call distributions.

-- Blue whales calls were found to be numerous over all the deep-water North Pacific Regions, especially and surprisingly in the NW Region. Blue whale calling peaked in autumn, but continued at reduced amounts in most areas during all seasons.

-- Many blue whales did not migrate, but they remained in the different Regions and continued to call throughout the year.

-- Fin whales calls were concentrated in localized deep water Regions at all latitudes in relatively large numbers during winter, and there were few calls in summer.

-- Fin whales did not have any noticeable migratory movement to the south in winter.

-- Humpback songs began seasonally in the deep waters of the NC Region, then moved to the middle and southern areas of the SE, skipping the intervening waters. Songs normally continued in the southern part of the SE Region throughout the winter.

-- Singing humpbacks in the SE Region mostly moved southward in December and January, northward in April/May, and they moved both to the south and the north during February and March.

-- During the unusual El Niño/La Niña conditions of the 1998/1999 season, there were no singing humpbacks in the SE Region.

-- The data on the occurrence of calling whales in the deep waters of these North Pacific Regions have allowed predictive assessments of their locations, seasonality, and movements. In addition, judgements can be made of potential effects of environmental perturbations (El Niño/La Niña) on whale calling in different Regions.

-- The reliability of such assessments and predictions has continued to increase with each additional set of data added to the call databases.

REPORTS FROM THIS PROGRAM

Watkins, William A., Mary Ann Daher, Joseph George, Velma Ronquille, and Amy Stanley. 1993. Unusual whale sound tracked by Navy SOSUS. Space and Naval Warfare Systems Command, Arlington VA. Unpublished report, 18 pp.

Watkins, William A., Mary Ann Daher, Joseph E. George, Darel L. Martin, Nancy A. DiMarzio, and Damon P. Gannon. 1997. Seasonal distribution of underwater whale sounds in the northeast Pacific recorded by Navy SOSUS. Report to SPAWAR and ONR. Unpublished report, 22 pp., 8 figs.

Watkins, William A., Mary Ann Daher, Joseph E. George, Darel L. Martin, Nancy A. DiMarzio, Damon P. Gannon, and G. M. Reppucci. 1998. North Pacific whale sound recordings. Abstract, The World Marine Mammal Science Conference, Monaco, 20-24 January 1998, p. 146.

Watkins, William A., Kristina Mullin, and Mary Ann Daher. 1995-1999. (Total of 45 reports) Analysis of the occurrence of calling whales in the North Pacific. Monthly Report for SERDP/ONR/NMFS, Summary and Analysis of Current Data from SOSUS arrays at Whidbey NOPF. Unpublished report, (each) text 2 pp., graphics 12 pp.

Watkins, William A. 1998. SOSUS monitoring of whale calls in the North Pacific. Presentation to CNO N45 Marine Mammal Seminar 7-8 April 1999, Crystal City Hilton, Arlington, VA.

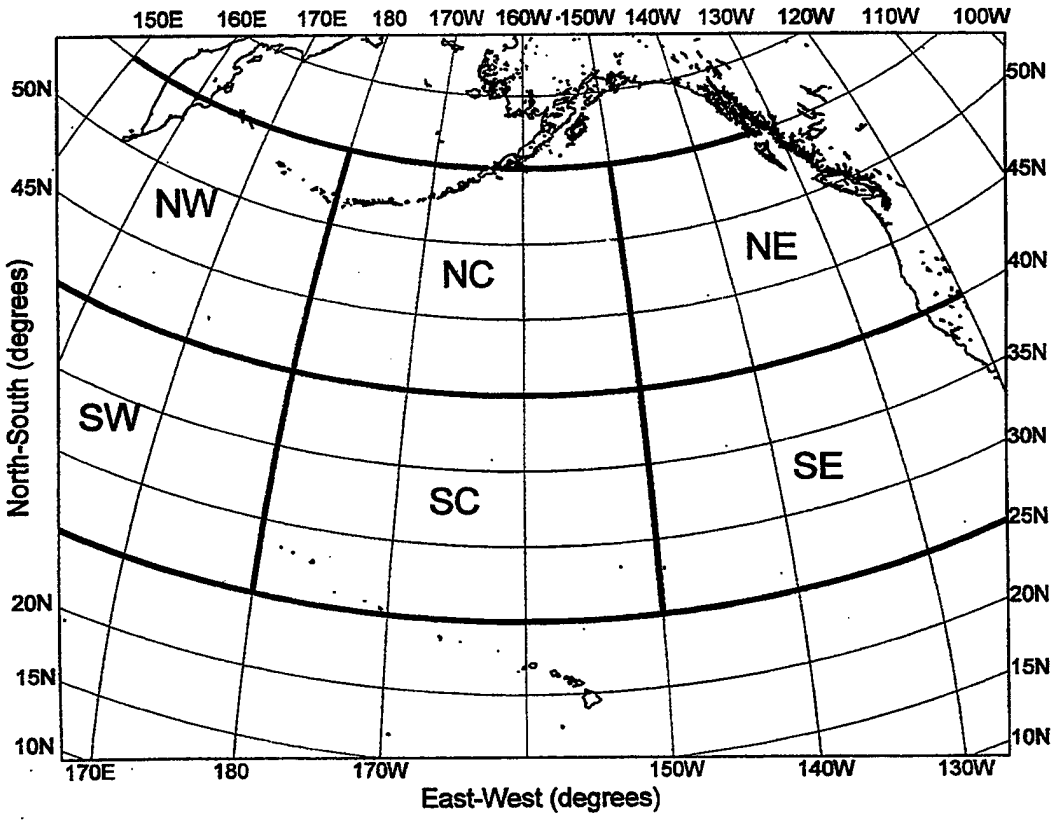
Watkins, William A. 1999. Whale signature analysis and distribution of sounds from IUSS data. Survey of Navy Funded Marine Mammal Research and Studies FY 98-99. Marine Mammal S&T Program, Office of Naval Research, 800 N. Quincy St., Arlington, VA, pp. 179-181.

Watkins, William A., and Mary Ann Daher. 1999. Whale call monitoring program from SOSUS arrays at NOPF, Whidbey Is., WA. SERDP IUSS Dual Uses Program Wrap-up, 28-29 September 1999, Bethesda, MD. Unpublished report, 25 pp.

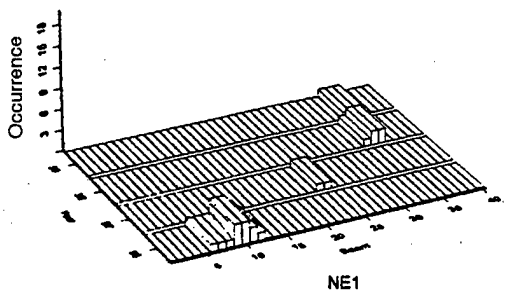
Watkins, William A., Mary Ann Daher, Gina M. Reppucci, Joseph E. George, Darel L. Martin, Nancy A. DiMarzio, and Damon F. Gannon. In press. Seasonality and distribution of whale calls in the North Pacific. Oceanography 13(1).

ACKNOWLEDGMENTS

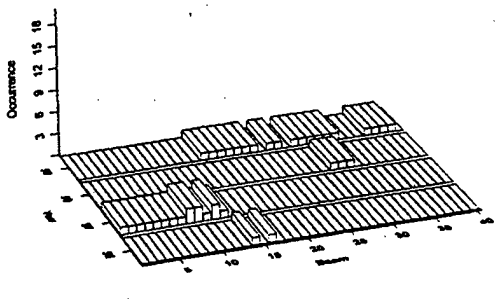
The consistent encouragement and direct participation of Navy personnel in these studies has been valuable and appreciated. We especially thank the cognizant Commands: CAPT. M. Mosier, CDR D. Geiger, CDR T. Concannon, and CDR T. Barrett. Support for this program has been from the SERDP Council, administered most recently by the U.S. Office of Naval Research (N00014-96-1-1130), from the ONR Marine Mammal Program, from CNO N45 Environmental Program, and from the Woods Hole Oceanographic Institution. The dedicated, highly experienced analysts responsible for recognition and consistent recording of the whale call data have been Joseph George, Darel Martin, and Scott Haga. At Woods Hole, database handling and analytic comparisons of the whale call information have been by Trevor Spradlin, Gina Reppucci, Kristina Mullin, Nancy DiMarzio, and Mary Ann Daher. Helpful comments on these series of data reports were made by Ernest Young, Marilyn Dahlheim, Robert Gisiner, Christopher Clark, Robert Spindel, Dennis Conlon, and Sue Ellen Moore.


150E
160E
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
50N
45N
40N
35N
30N
25N
20N
15N
10N
NW
NC
NE
SW
SC
SE
North-South (degrees)
170E
180
170W
150W
140W
130W
East-West (degrees)

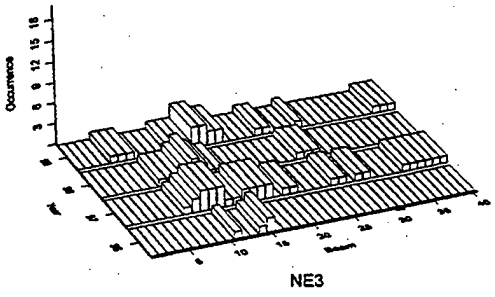
Occurrence of blue whales in NE for January



NE1

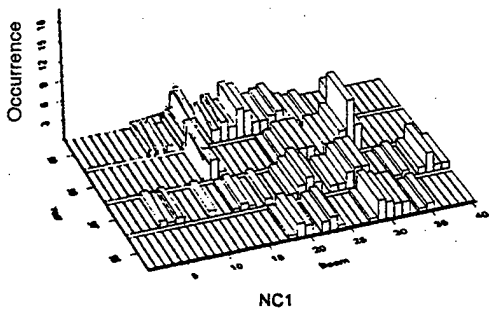


NE2

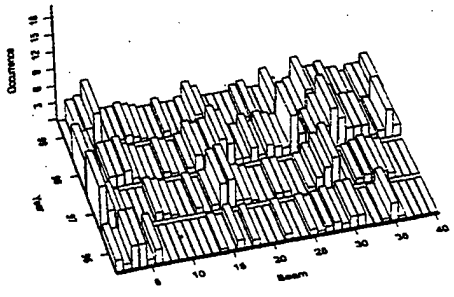


NE3

Occurrence of blue whales in NC for January

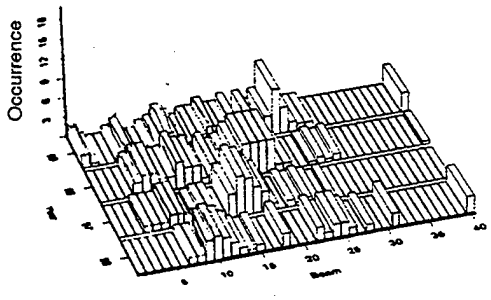


NC1

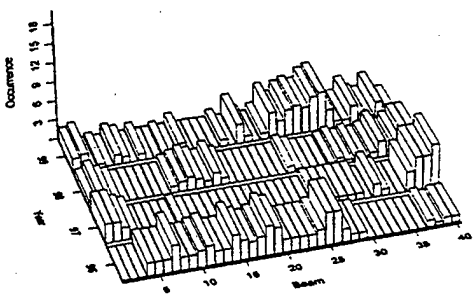


NC2

Occurrence of blue whales in NW for January

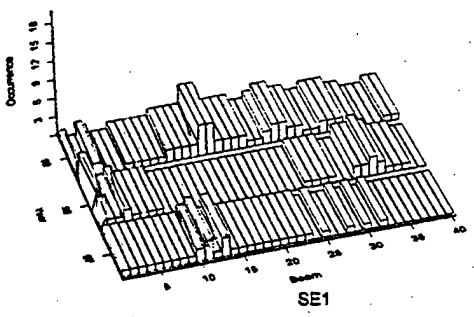


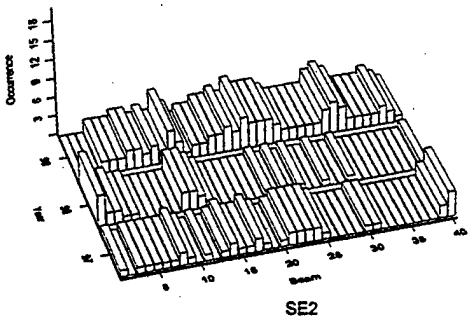
NW1

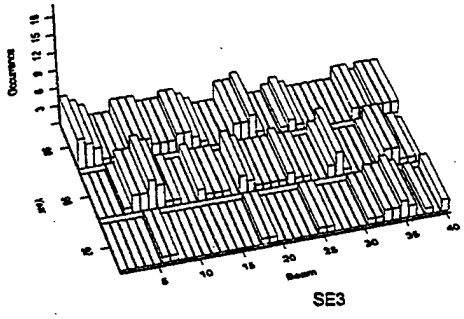


NW2

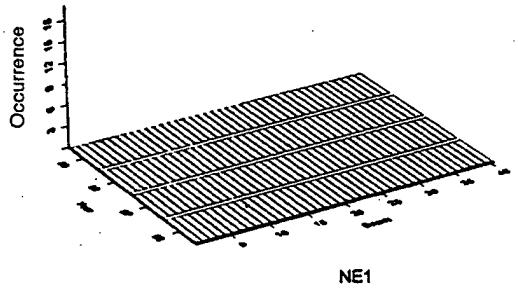
Occurrence of blue whales in SE for January

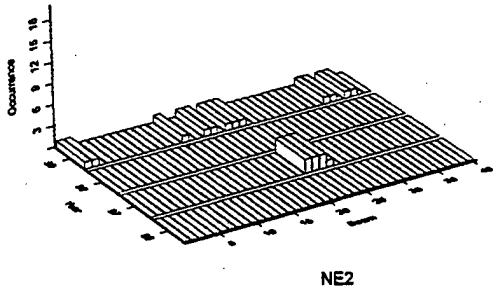


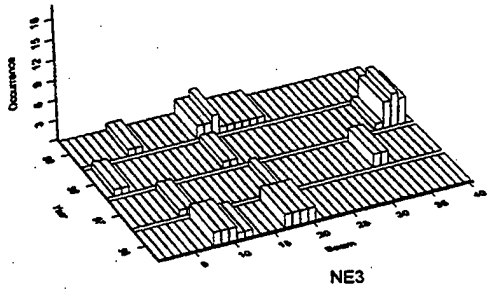




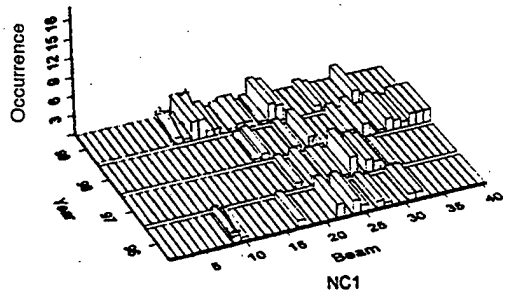
Occurrence of blue whales in NE for February

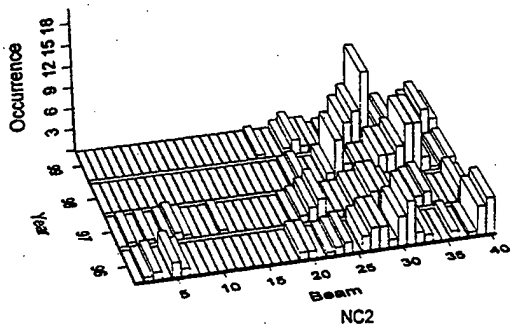




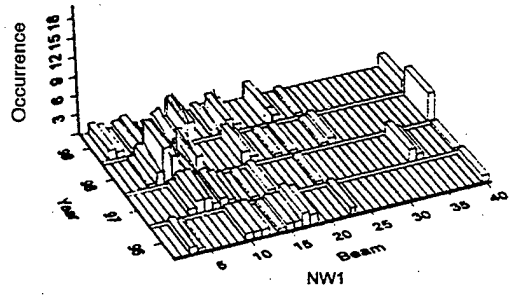


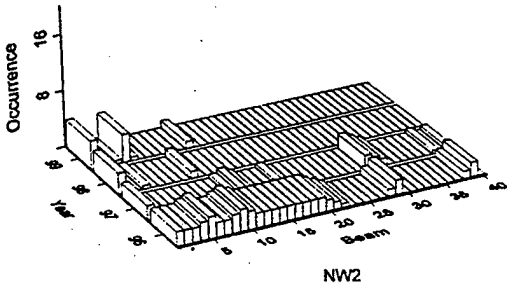
Occurrence of blue whales in NC for February



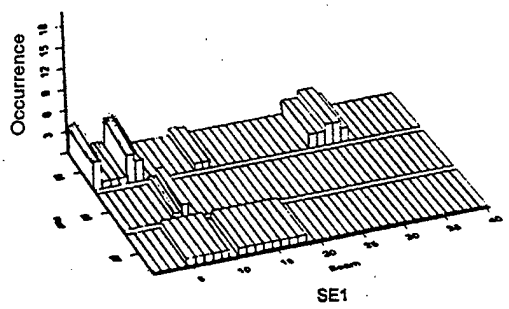


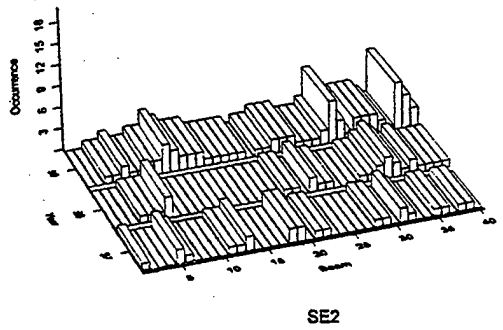
Occurrence of blue whales in NW for February

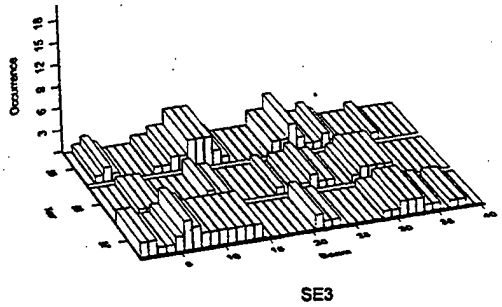




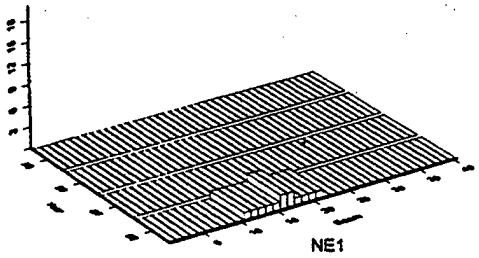
Occurrence of blue whales in SE for February



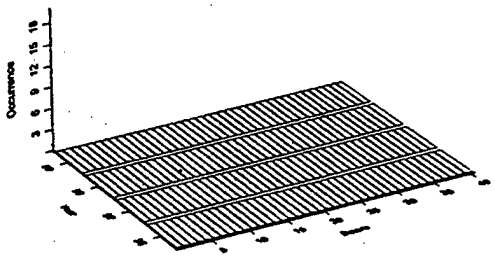




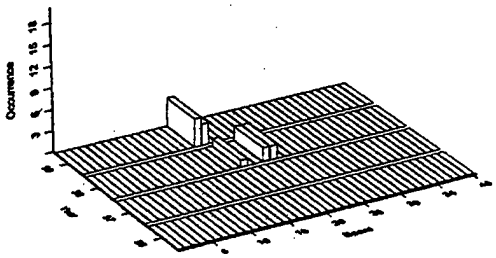
Occurrence of blue whales in NE for March



NE1

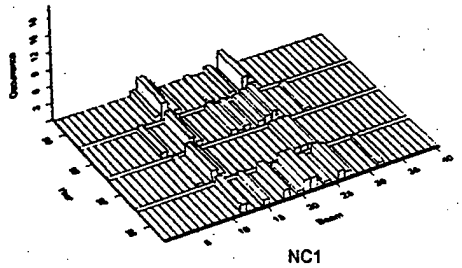


NE2

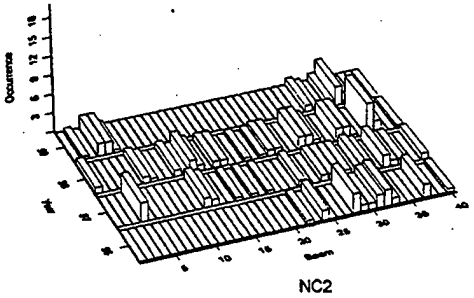


NE3

Occurrence of blue whales in NC for March

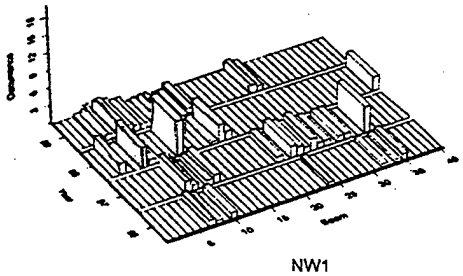


NC1

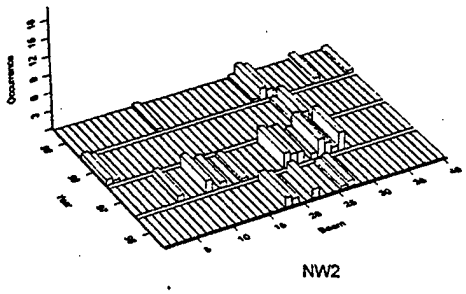


NC2

Occurrence of blue whales in NW for March

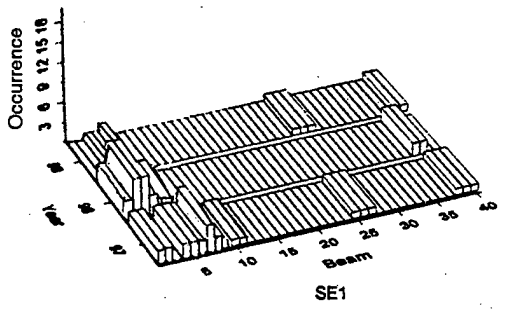


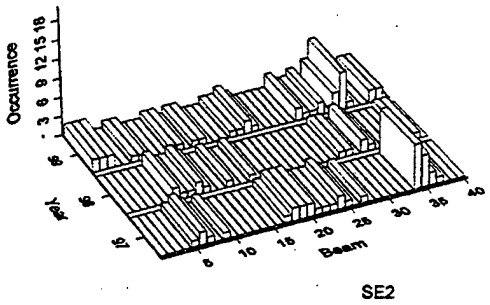
NW1

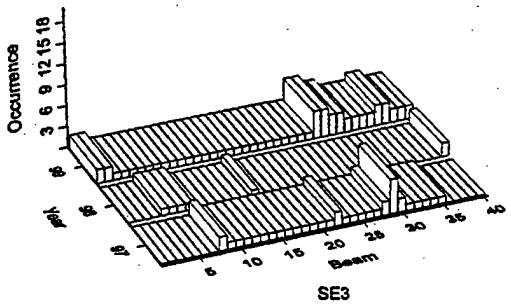


NW2

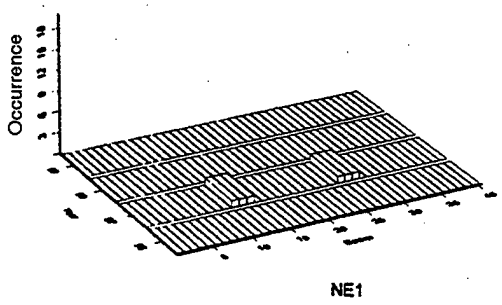
Occurrence of blue whales in SE for March



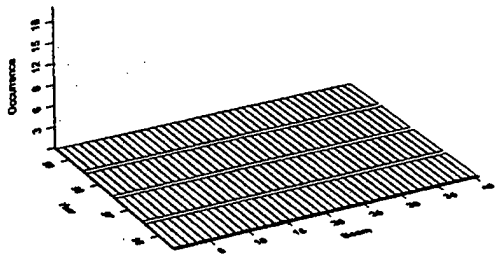




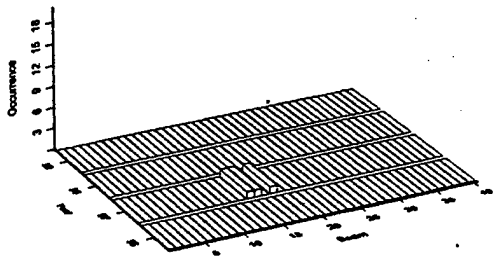
Occurrence of blue whales in NE for April



NE1

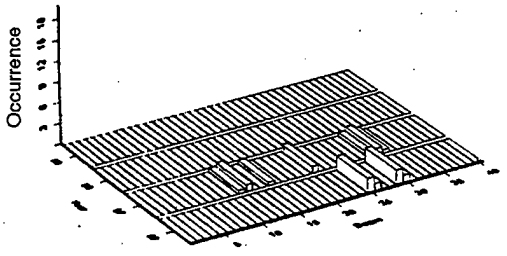


NE2

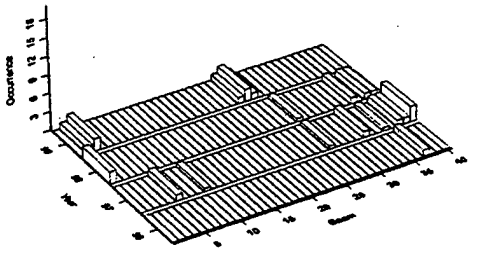


NE3

Occurrence of blue whales in NC for April

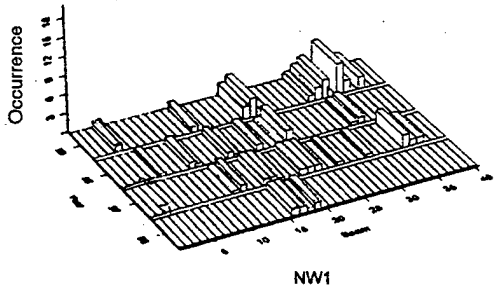


NC1

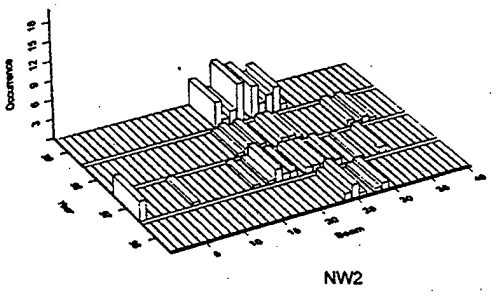


NC2

Occurrence of blue whales in NW for April

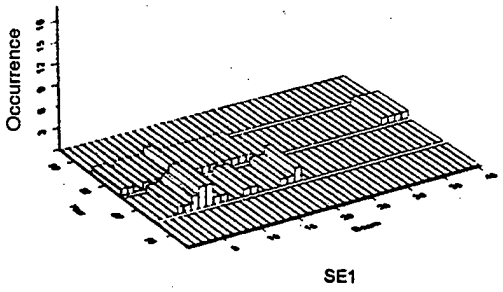


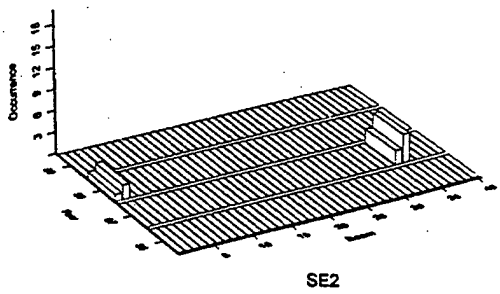
NW1

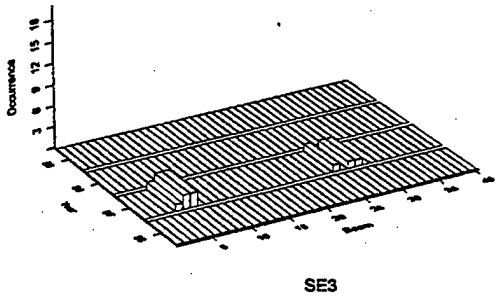


NW2

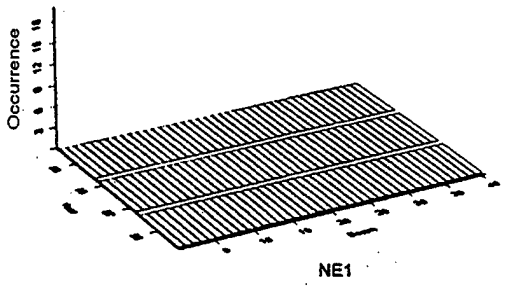
Occurrence of blue whales in SE for April

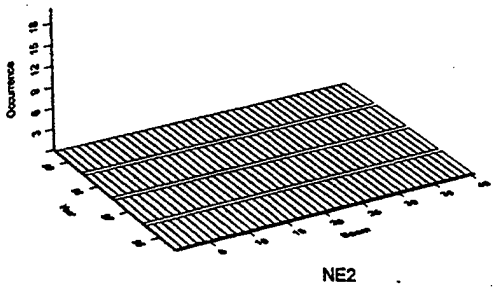


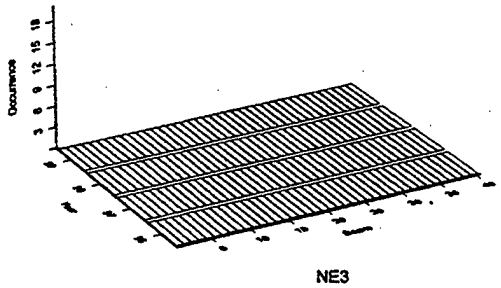




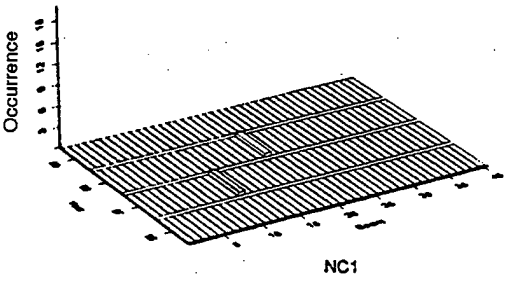
Occurrence of blue whales in NE for May

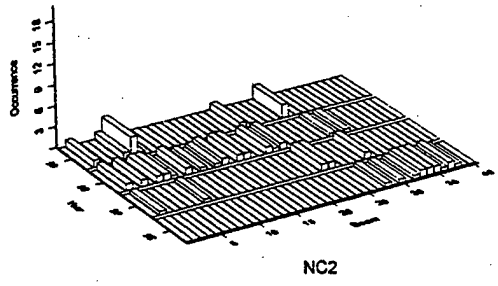




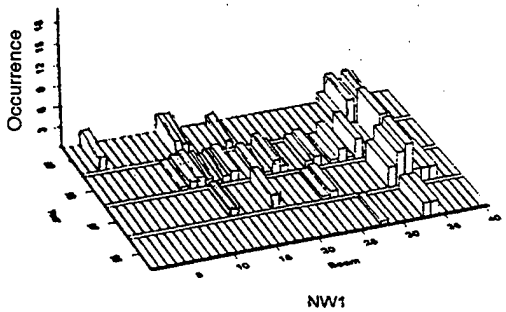


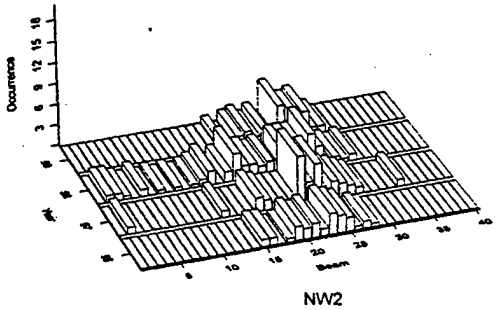
Occurrence of blue whales in NC for May



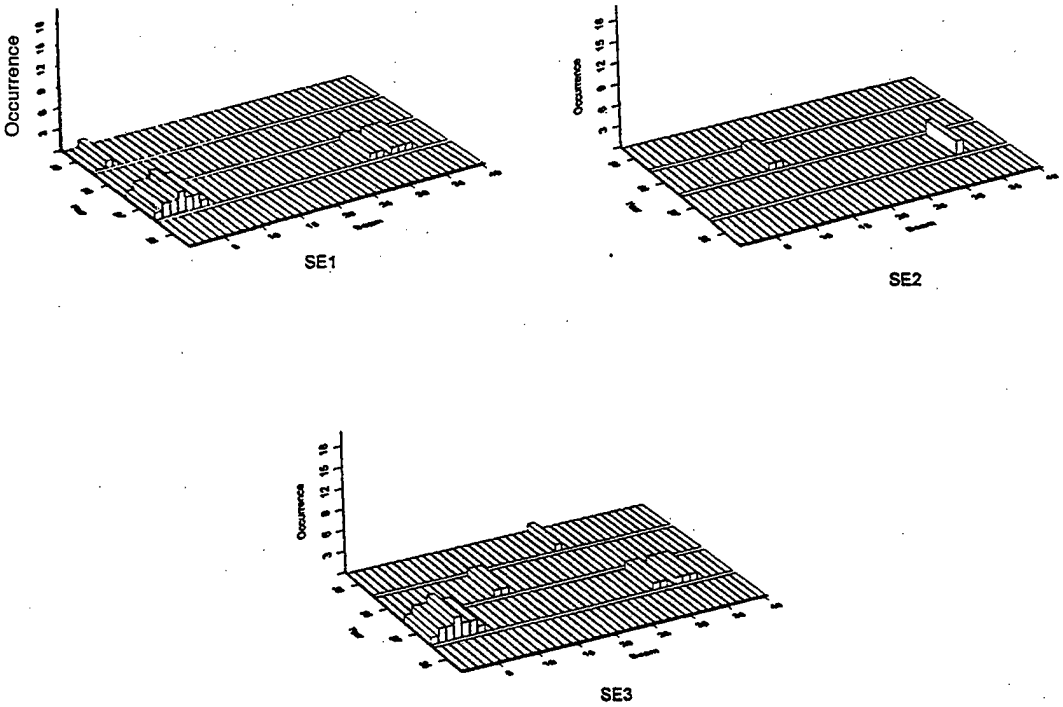


Occurrence of blue whales in NW for May

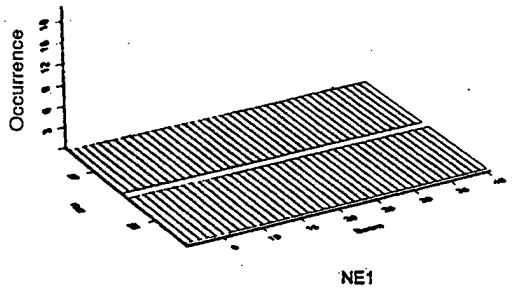




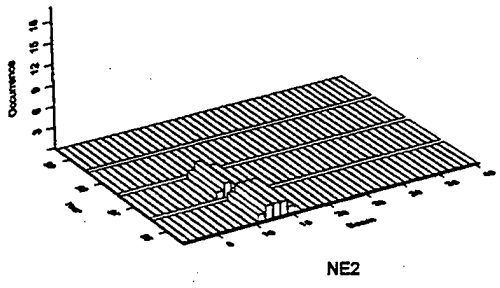
Occurrence of blue whales in SE for May



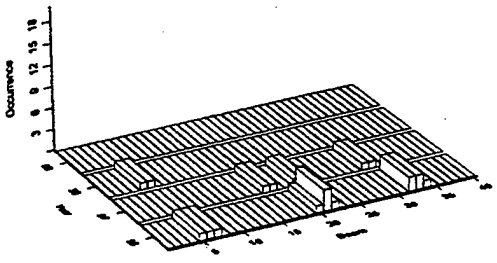
Occurrence of blue whales in NE for June



NE1

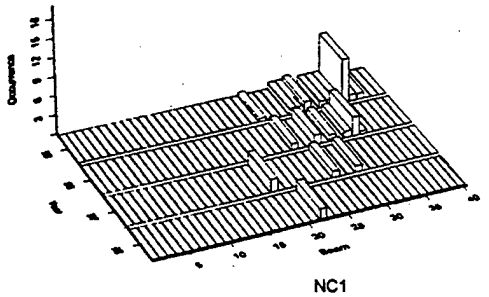


NE2

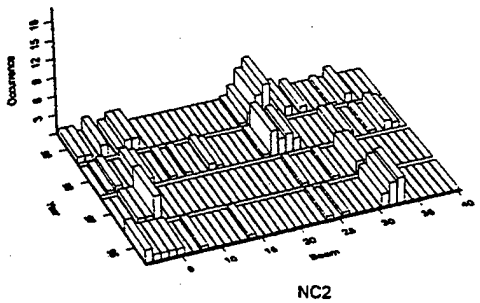


NE3

Occurrence of blue whales in NC for June

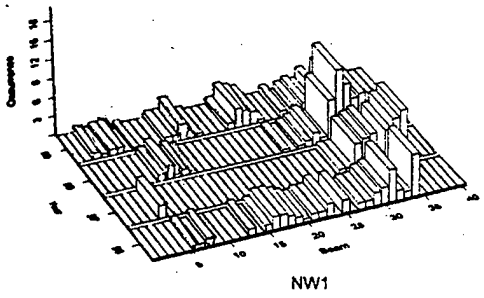


NC1

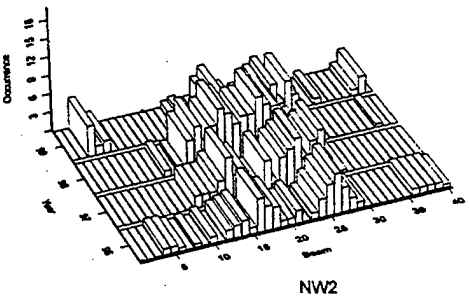


NC2

Occurrence of blue whales in NW for June

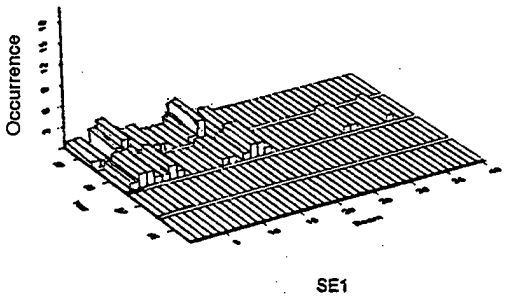


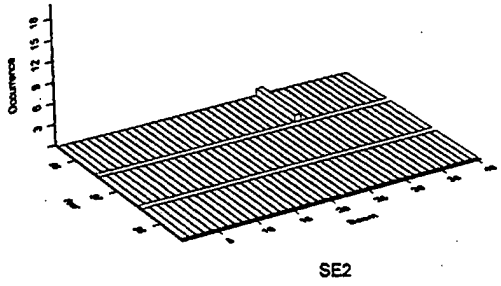
NW1

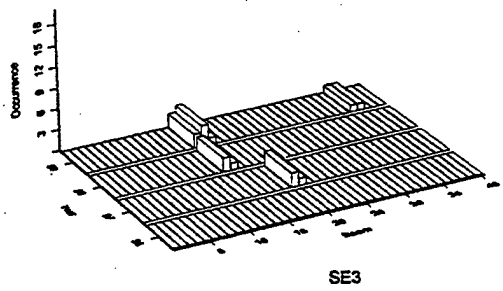


NW2

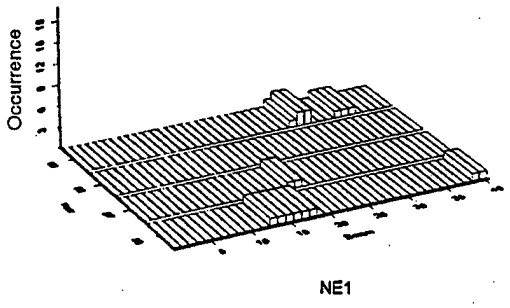
Occurrence of blue whales in SE for June



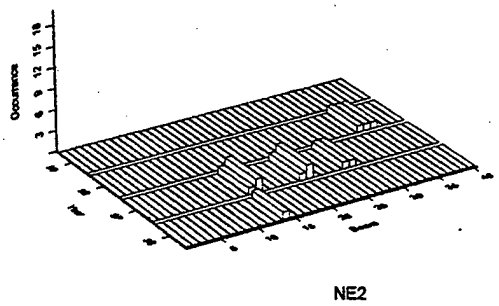




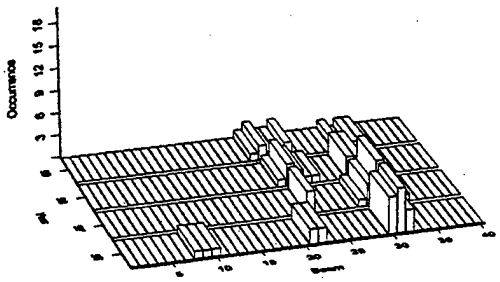
Occurrence of blue whales in NE for July



NE1

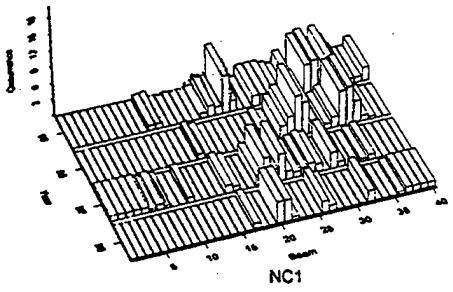


NE2

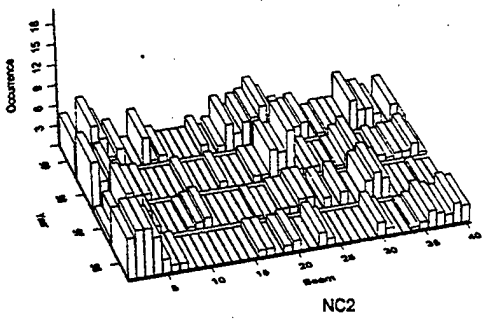


NE3

Occurrence of blue whales in NC for July

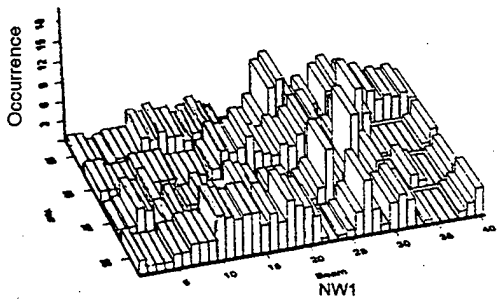


NC1

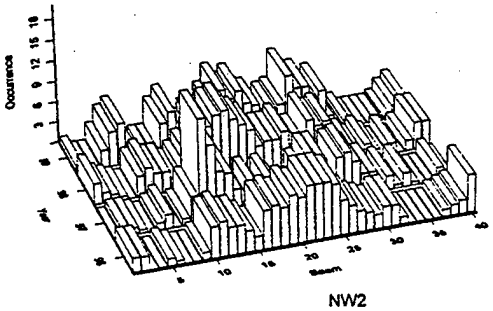


NC2

Occurrence of blue whales in NW for July

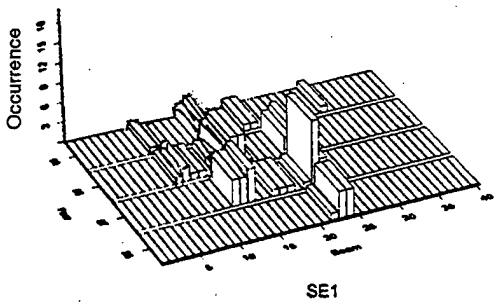


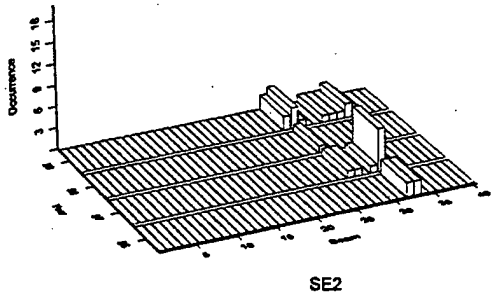
NW1

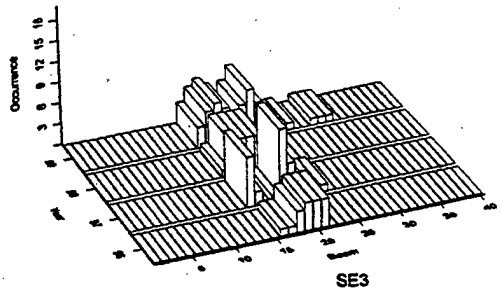


NW2

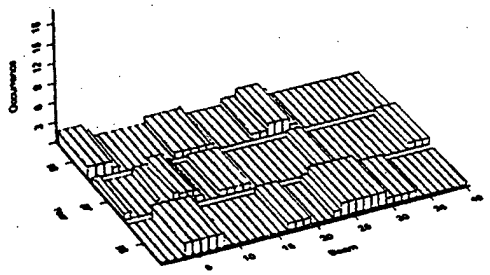
Occurrence of blue whales in SE for July



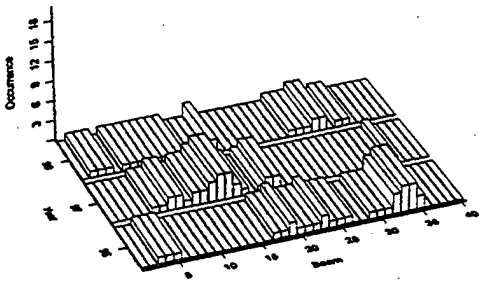




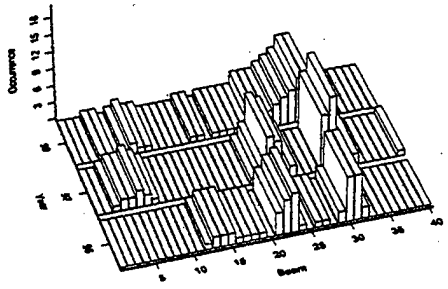
Occurrence of blue whales in NE for August



NE1

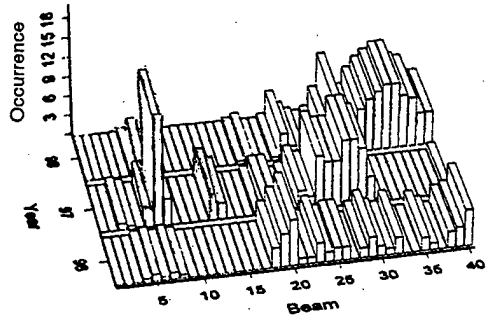


NE2

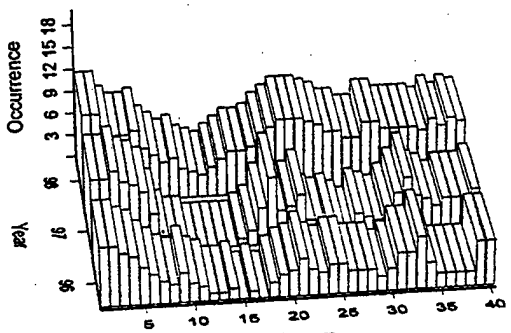


NE3

Occurrence of blue whales in NC for August

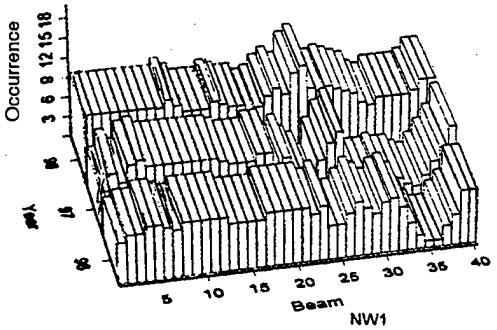


NC1

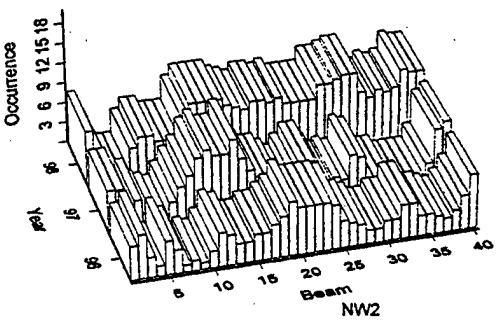


NC2

Occurrence of blue whales in NW for August

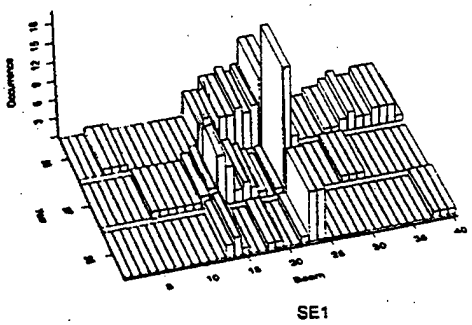


NW1

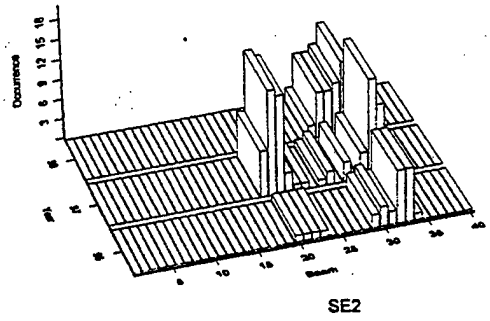


NW2

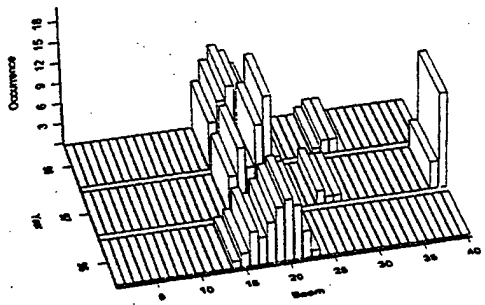
Occurrence of blue whales in SE for August



SE1

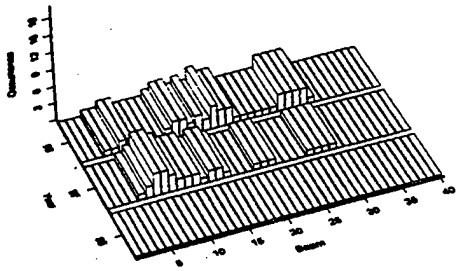


SE2

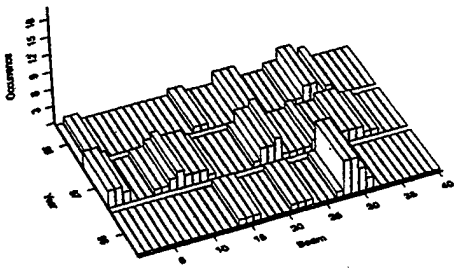


SE3

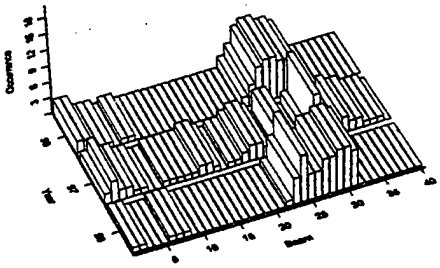
Occurrence of blue whales in NE for September



NE1

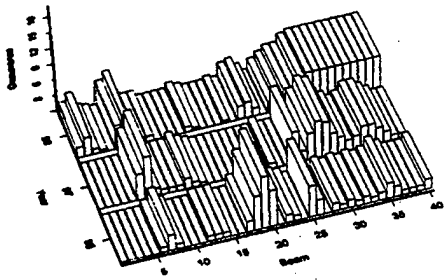


NE2

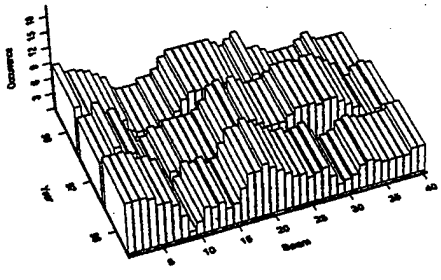


NE3

Occurrence of blue whales in NC for September

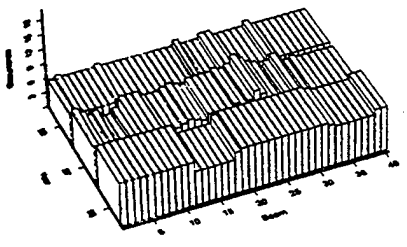


NC1

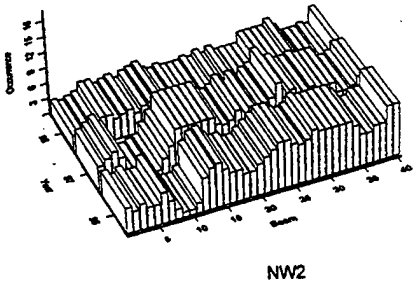


NC2

Occurrence of blue whales in NW for September

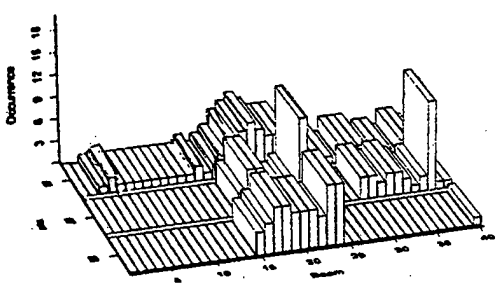


NW1

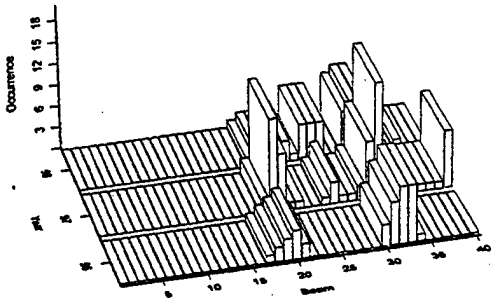


NW2

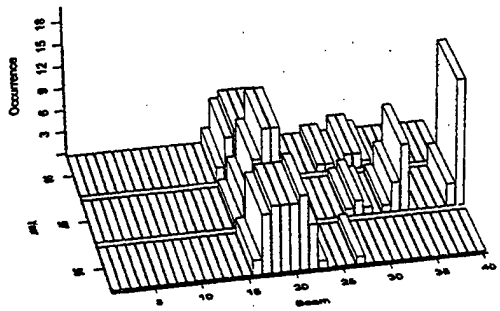
Occurrences of blue whales in SE for September



SE1

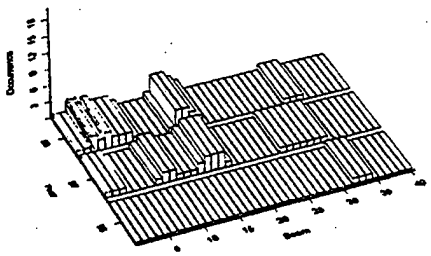


SE2

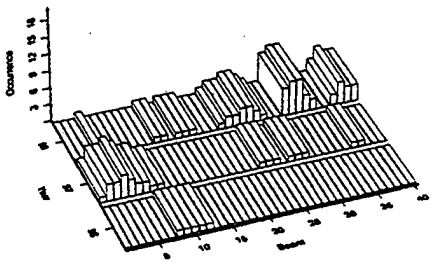


SE3

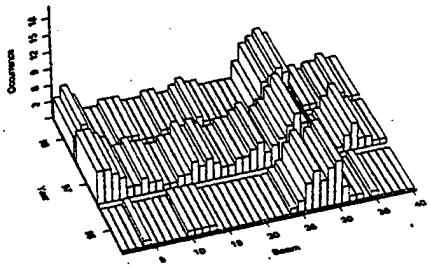
Occurrence of blue whales in NE for October



NE1

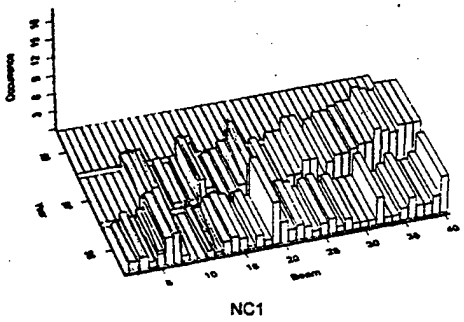


NE2

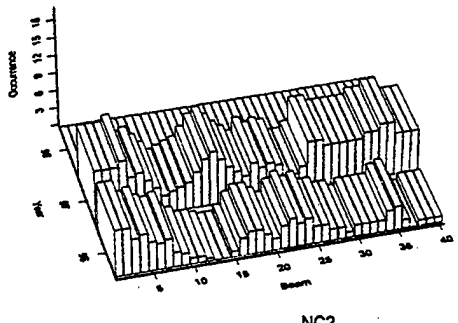


NE3

Occurrence of blue whales in NC for October
1998 array is down

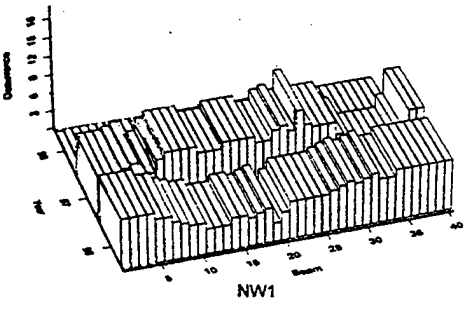


NC1

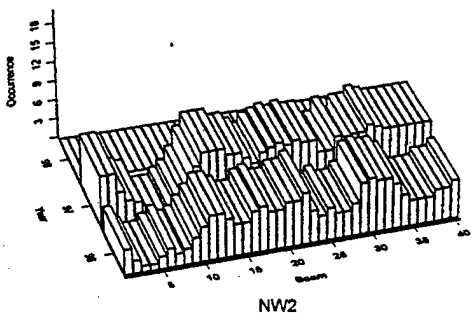


NC2

Occurrence of blue whales in NW for October
1998 array is down

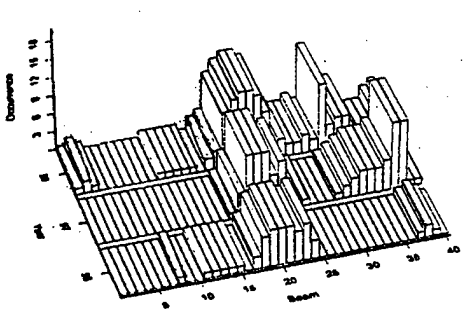


NW1

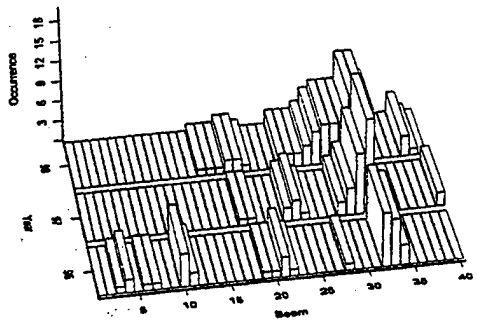


NW2

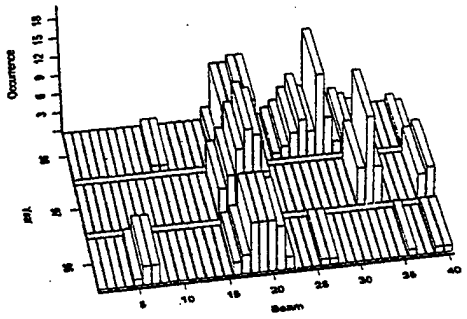
Occurrence of blue whales in SE for October



SE1

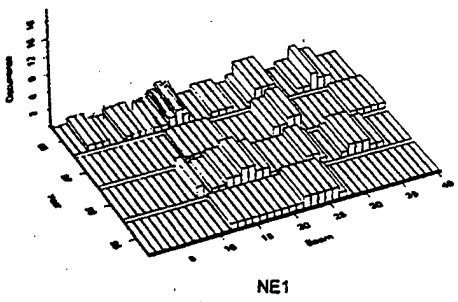


SE2

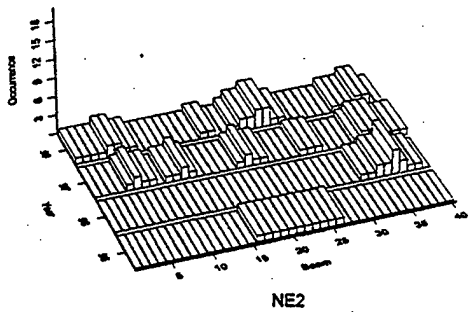


SE3

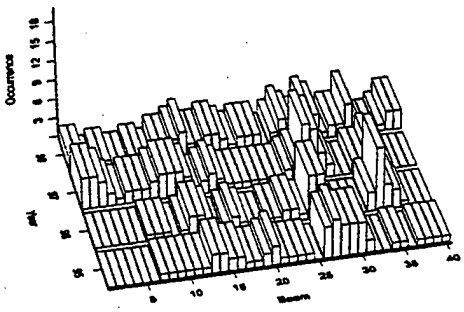
Occurrence of blue whales in NE for November



NE1

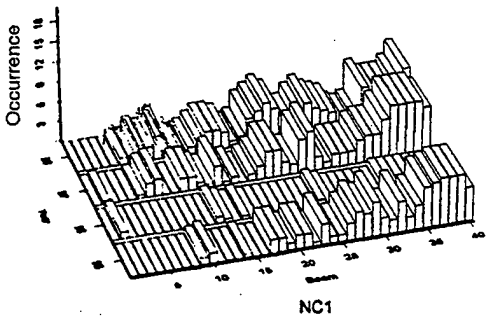


NE2

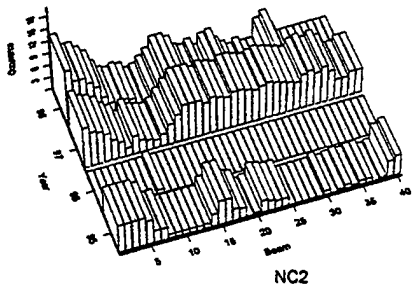


NE3

Occurrence of blue whales in NC for November

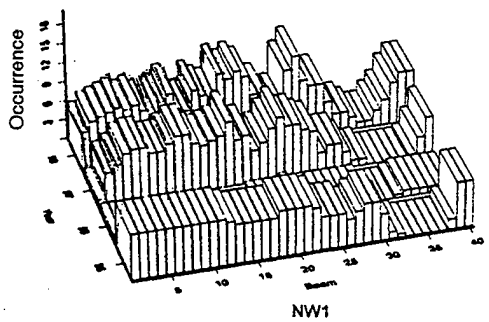


NC1

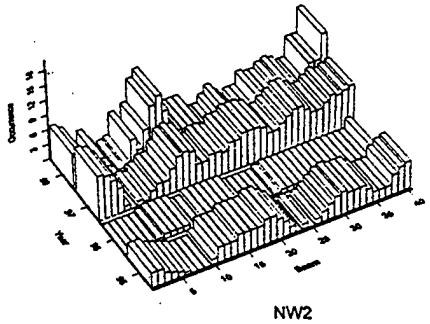


NC2

Occurrence of blue whales in NW for November

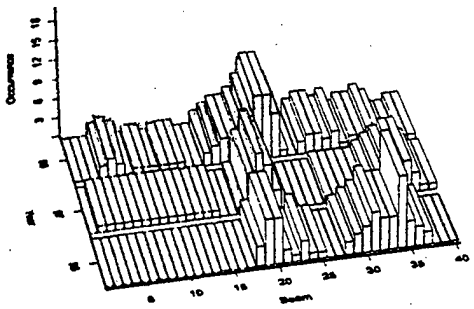


NW1

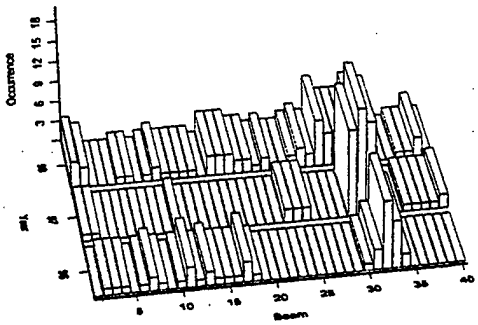


NW2

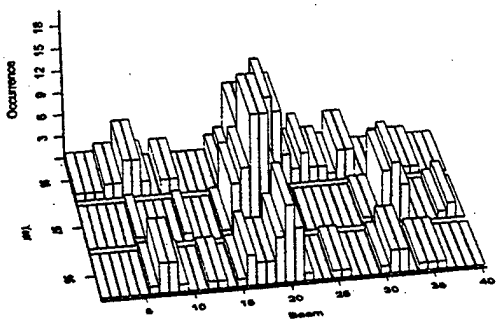
Occurrence of blue whales in SE for November



SE1

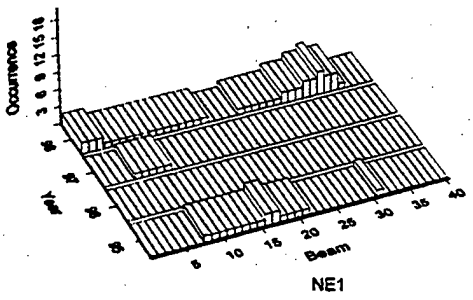


SE2

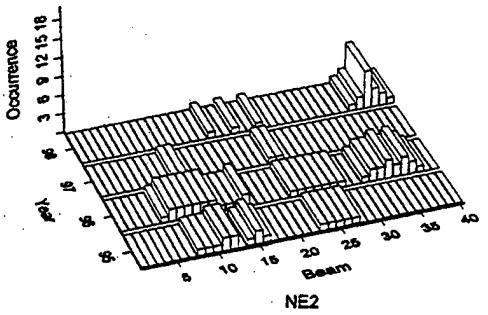


SE3

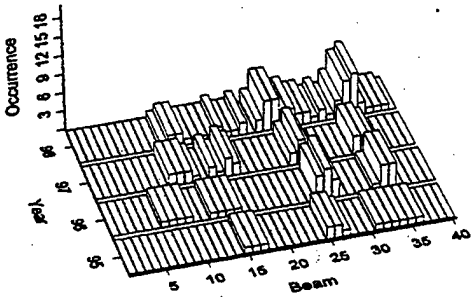
Occurrence of blue whale in NE for December



NE1

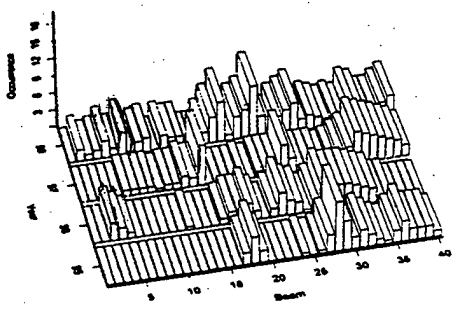


NE2

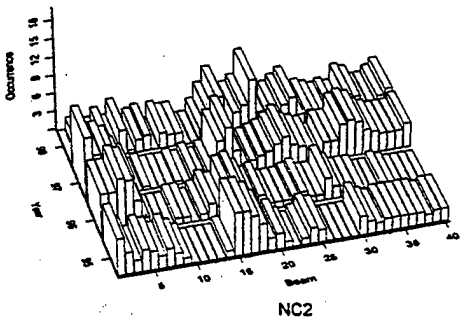


NE3

Occurrence of blue whales in NC for December

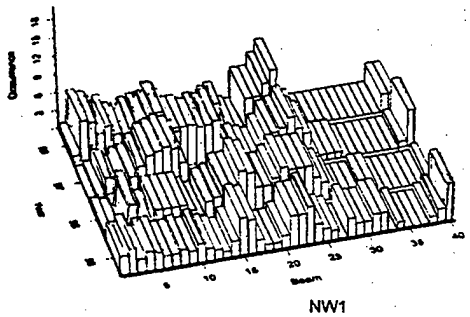


NC1

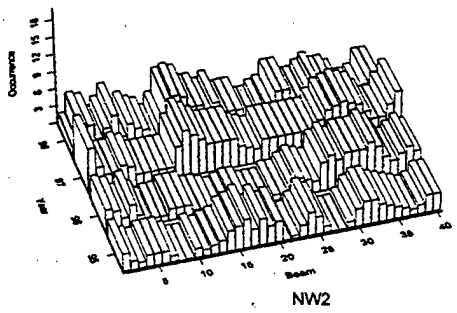


NC2

Occurrence of blue whales in NW for December

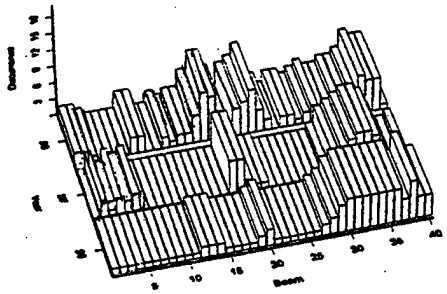


NW1

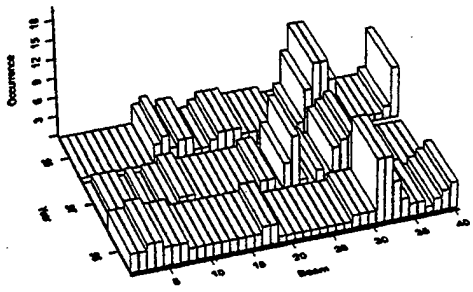


NW2

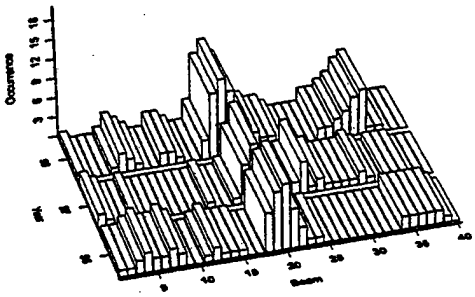
Occurrence of blue whales in SE for December



SE1

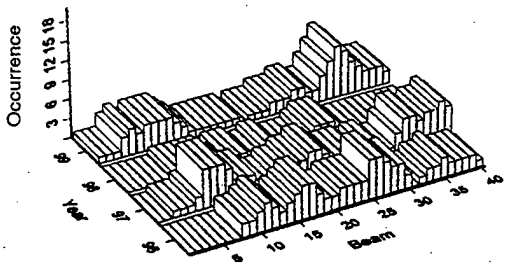


SE2

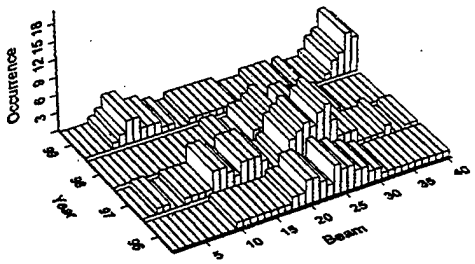


SE3

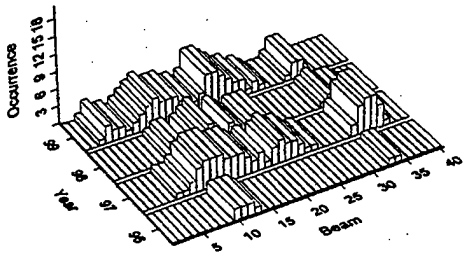
Occurrence of 'F' type fin whale calls in NE for January



NE1

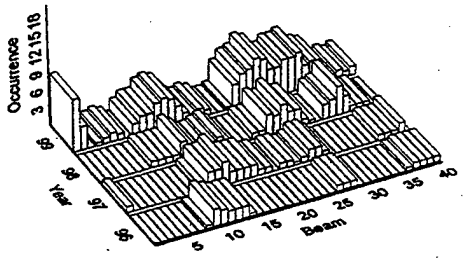


NE2

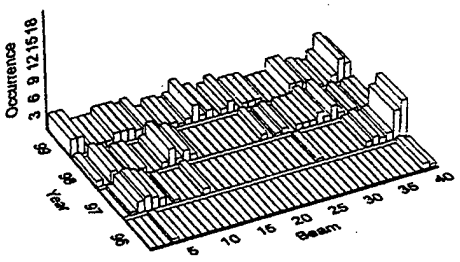


NE3

Occurrence of 'F' type fin whale calls in NC for January

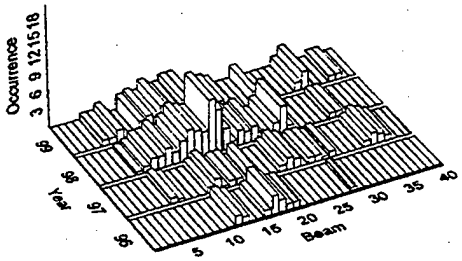


NC1

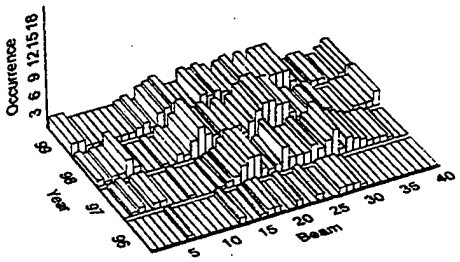


NC2

Occurrence of 'F' type fin whale calls in NW for January

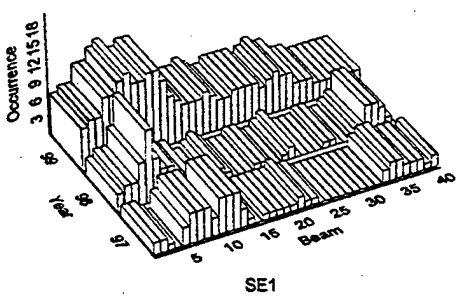


NW1

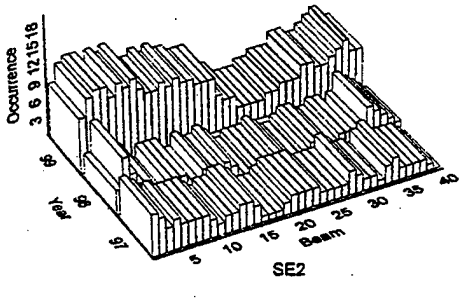


NW2

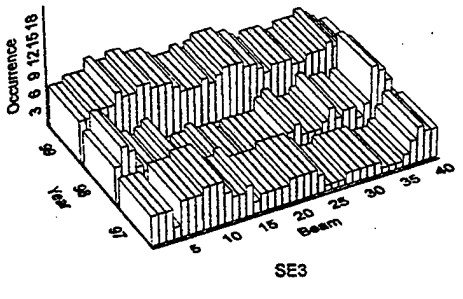
Occurrence of 'F' type fin whale calls in SE for January



SE1

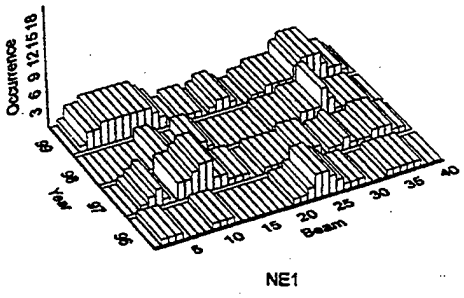


SE2

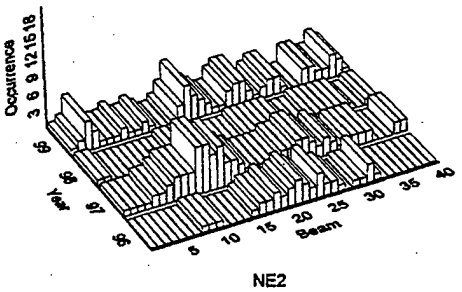


SE3

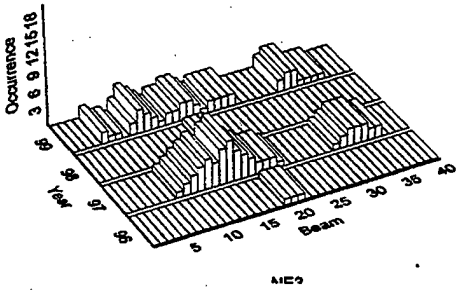
Occurrence of 'F' type fin whale calls in February



NE1

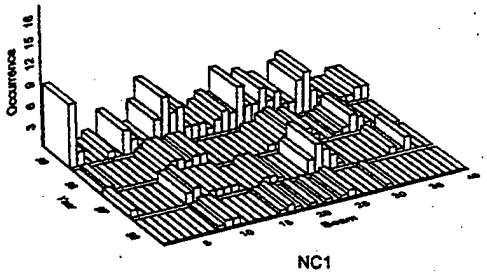


NE2

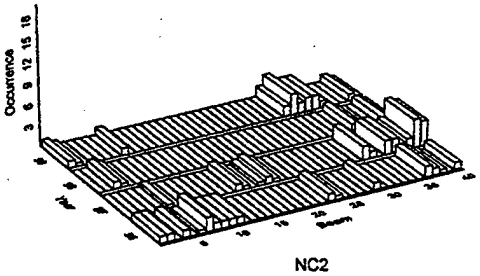


NE3

Occurrence of 'F' type fin whale calls in NC for February

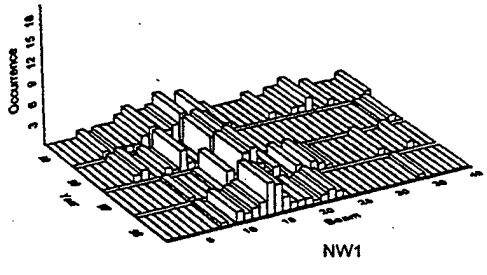


NC1

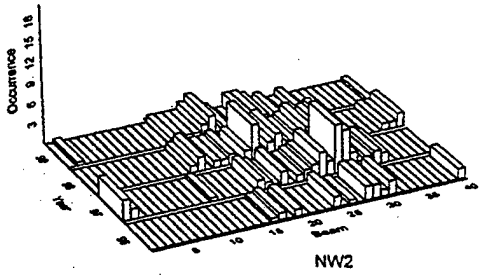


NC2

Occurrence of 'F' type fin whale calls in NW for February

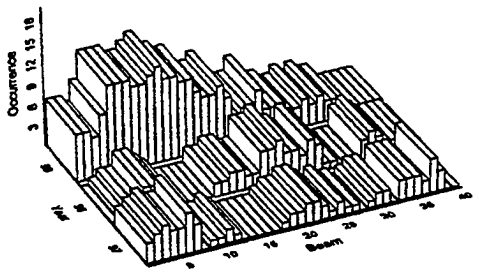


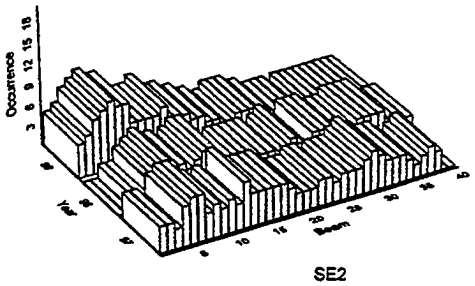
NW1

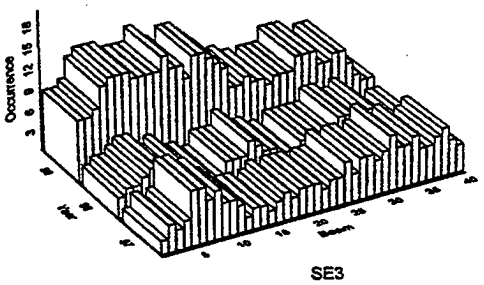


NW2

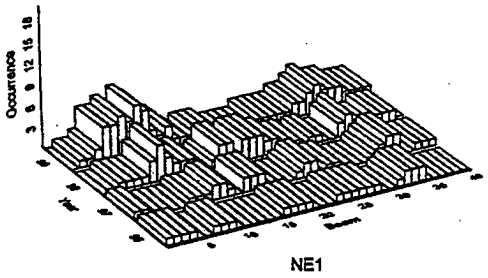
Occurrence of 'F' type fin whale calls in SE for February



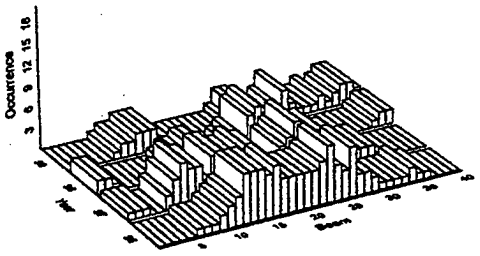




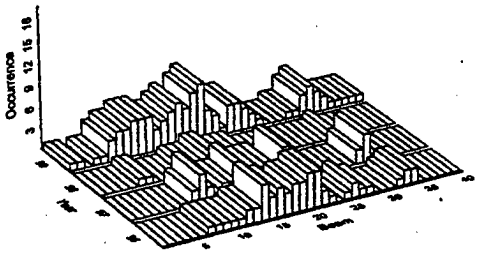
Occurrence of 'F' type fin whale calls in NE for March



NE1

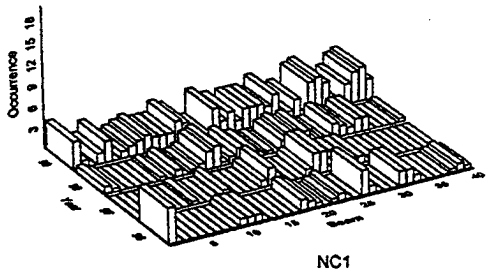


NE2

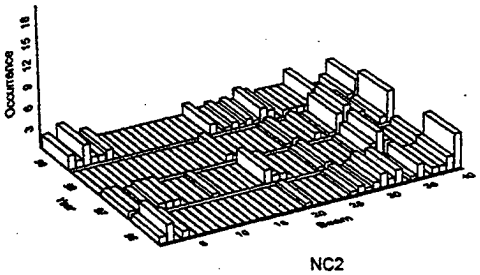


NE3

Occurrence of 'F' type fin whale calls in NC for March

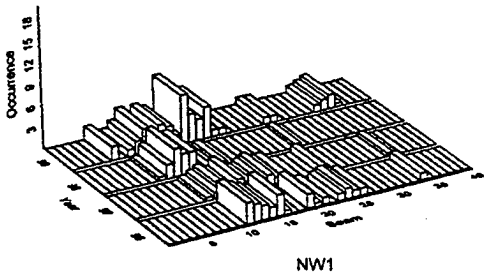


NC1

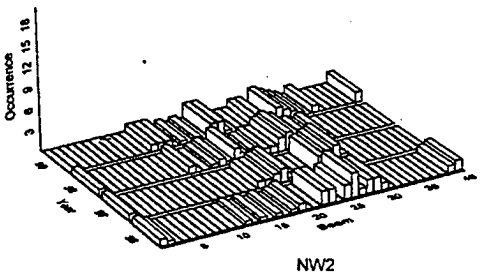


NC2

Occurrence of 'F' type fin whale calls in NW for March

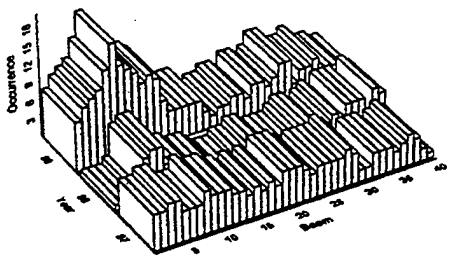


NW1

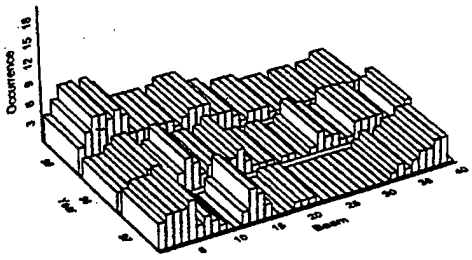


NW2

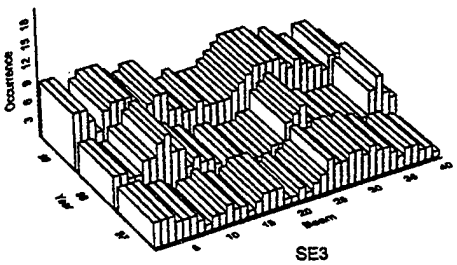
Occurrence of 'F' type fin whale calls in SE for March



SE1

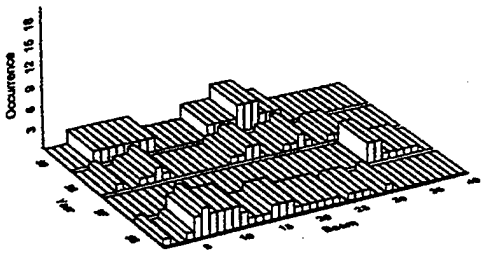


SE2

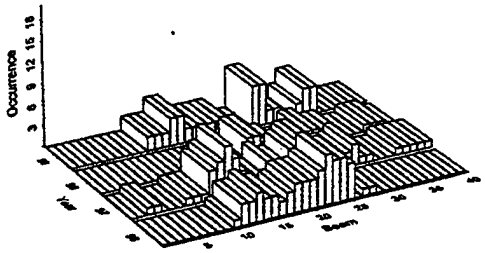


SE3

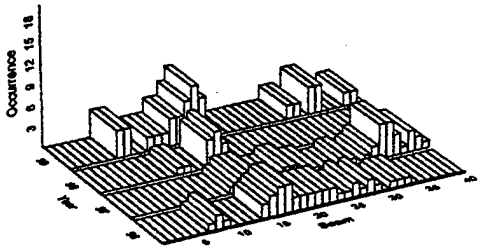
Occurrence of 'F' type fin whale calls in NE for April



NE1

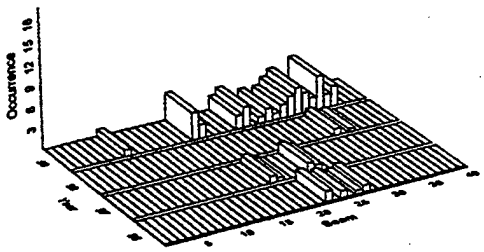


NE2

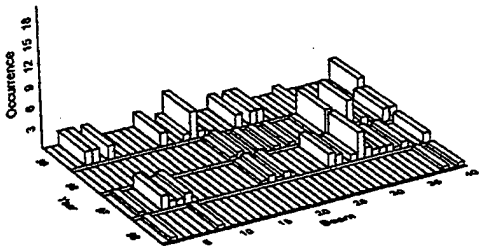


NE3

Occurrence of 'F' type fin whale calls in NC for April

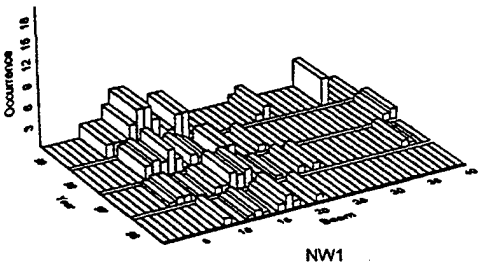


NC1

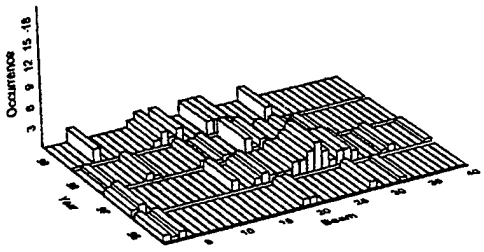


NC2

Occurrence of 'F' type fin whale calls in NW for April

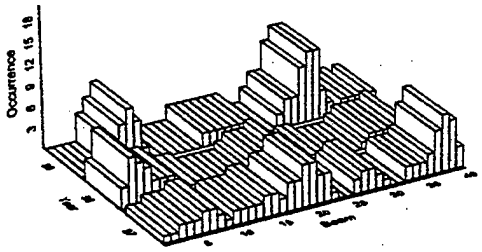


NW1

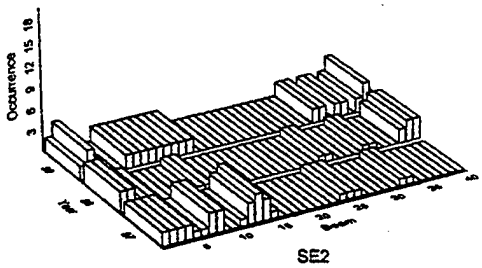


NW2

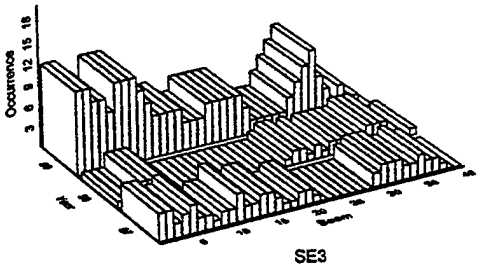
Occurrence of 'F' type fin whale calls in SE for April



SE1

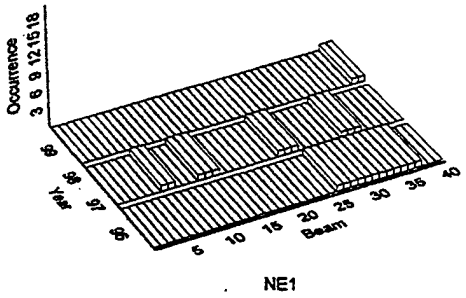


SE2

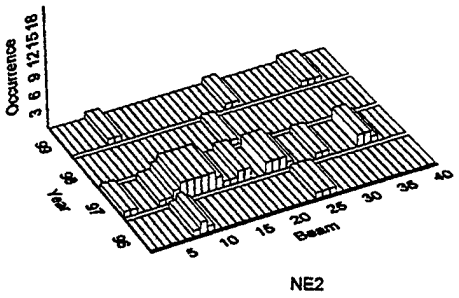


SE3

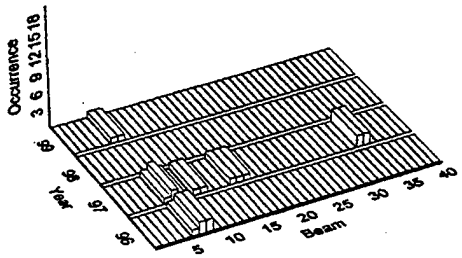
Occurrence of 'F' type fin whale calls in NE for May



NE1

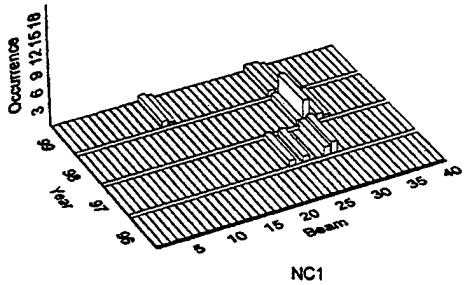


NE2

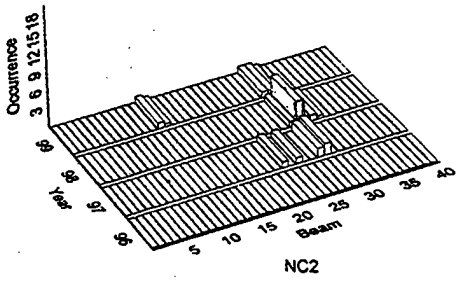


NE3

Occurrence of 'F' type fin whale calls in NC for May

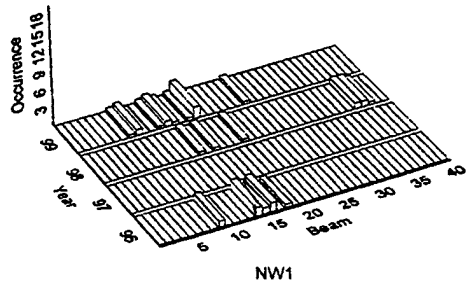


NC1

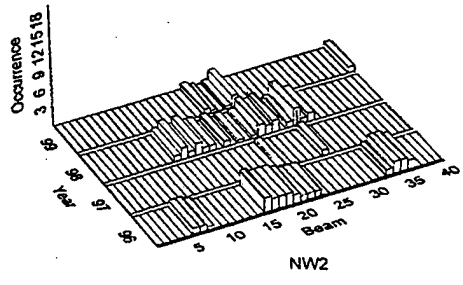


NC2

Occurrence of 'F' type fin whale calls in NW for May

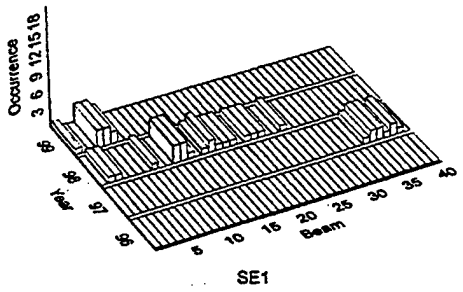


NW1

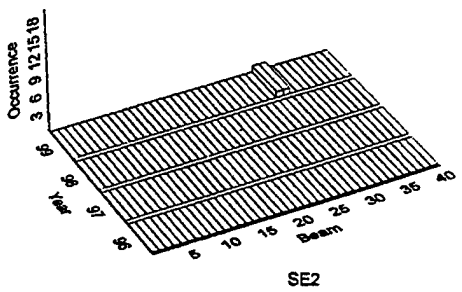


NW2

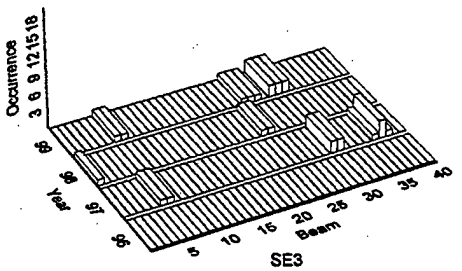
Occurrence of 'F' type fin whale calls in SE for May



SE1

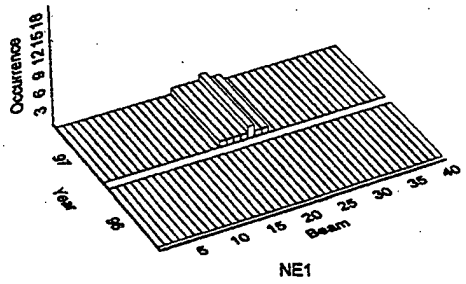


SE2

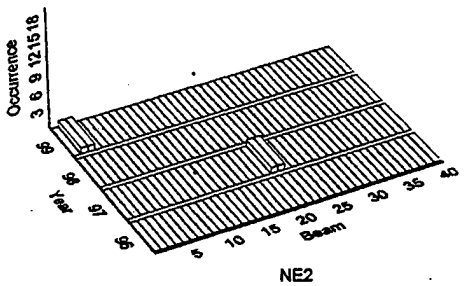


SE3

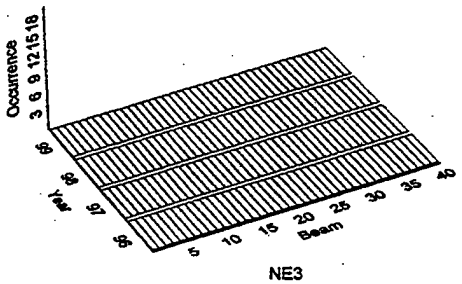
Occurrence of 'F' type fin whale calls in NE for June



NE1

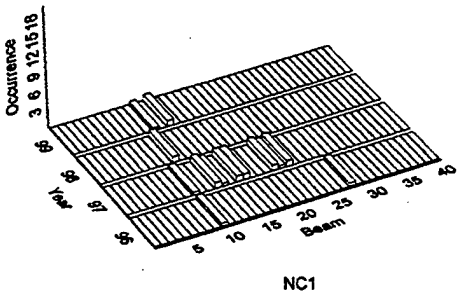


NE2

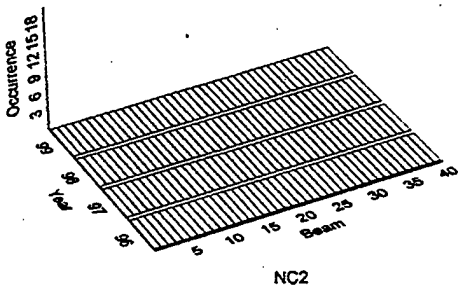


NE3

Occurrence of 'F' type fin whale calls in NC for June

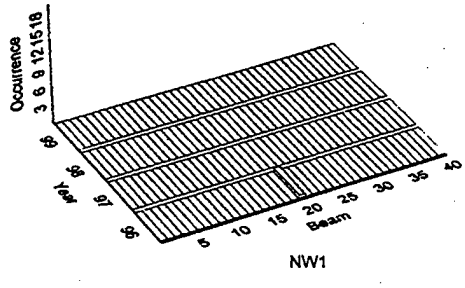


NC1

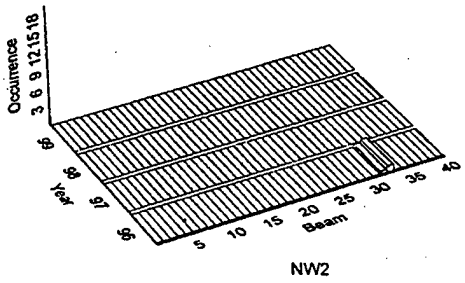


NC2

Occurrence of 'F' type fin whale calls in NW for June

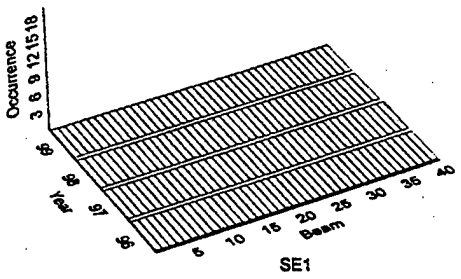


NW1

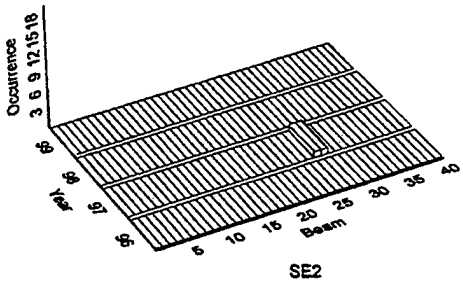


NW2

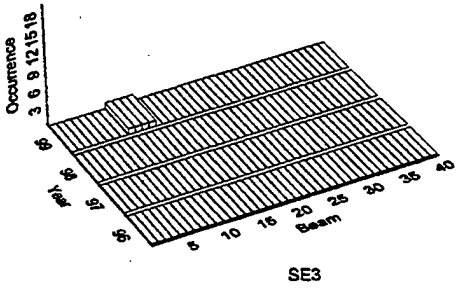
Occurrence of 'F' type fin whale calls in SE for June
**No data taken for 1998



SE1

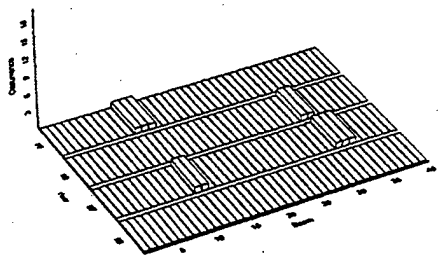


SE2

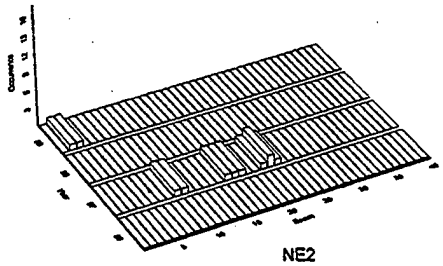


SE3

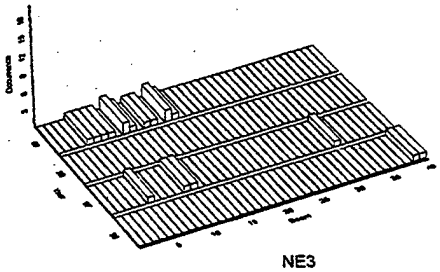
Occurrence of 'F' type fin whale calls in NE for July



NE1

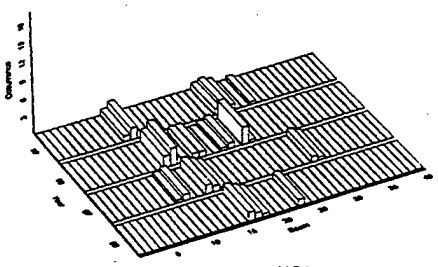


NE2

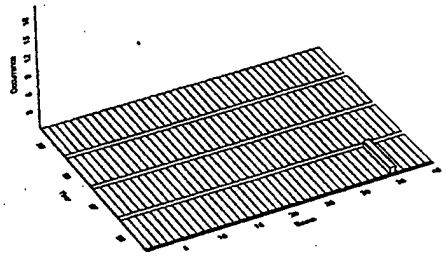


NE3

Occurrence of 'F' type fin whale calls in NC for July

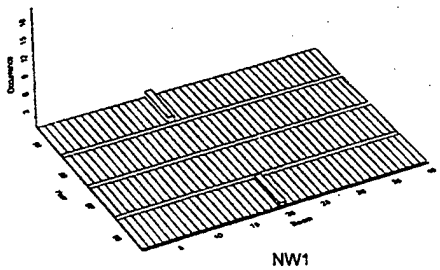


NC1

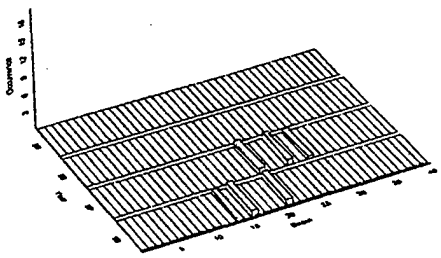


NC2

Occurrence of 'F' type fin whale calls in NW for July

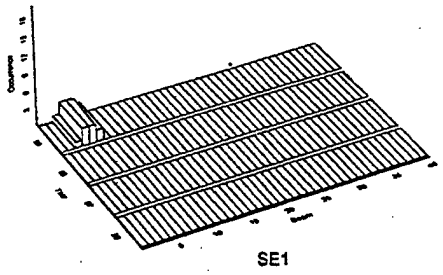


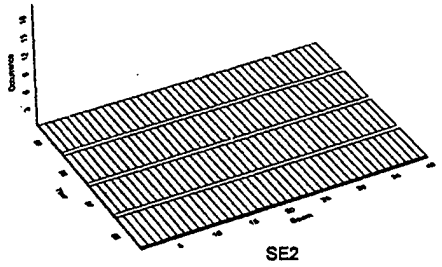
NW1

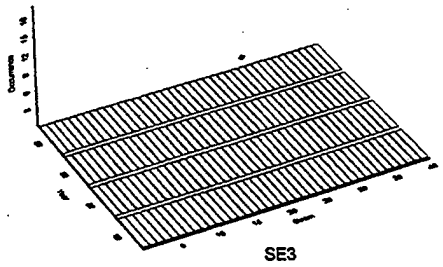


NW2

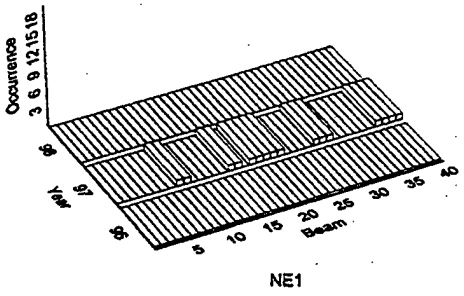
Occurrence of 'F' type fin whale calls in SE for July


SE1

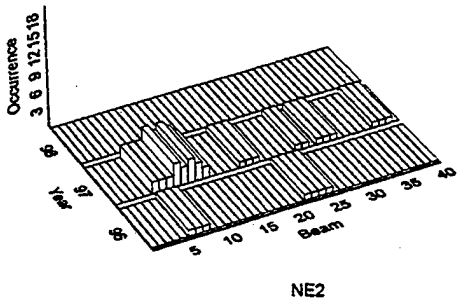

SE2


SE3

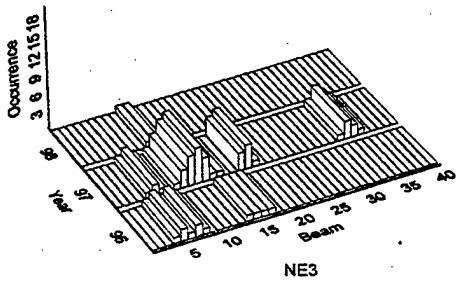
Occurrence of 'F' type fin whale calls in NE for August



NE1

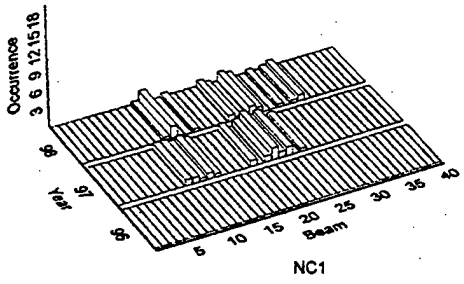


NE2

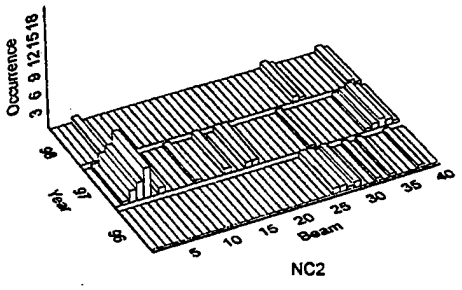


NE3

Occurrence of 'F' type fin whale calls in NC for August

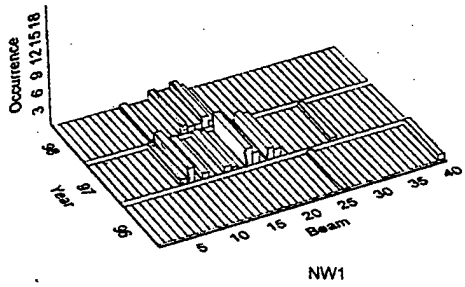


NC1

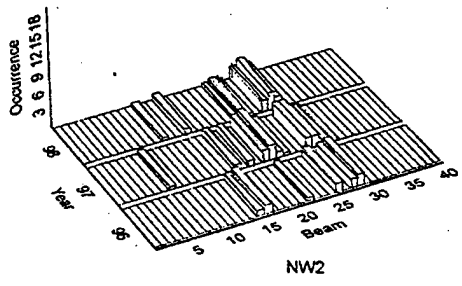


NC2

Occurrence of 'F' type fin whale calls in NW for August

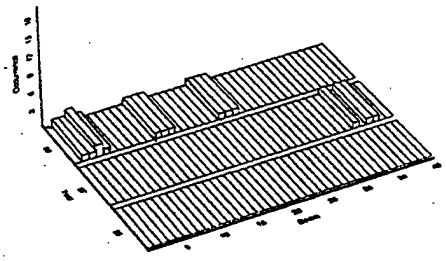


NW1

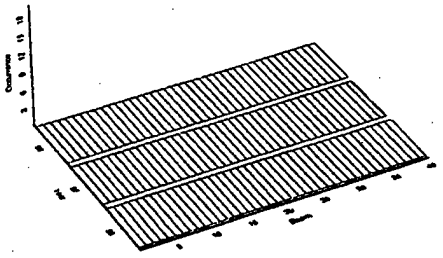


NW2

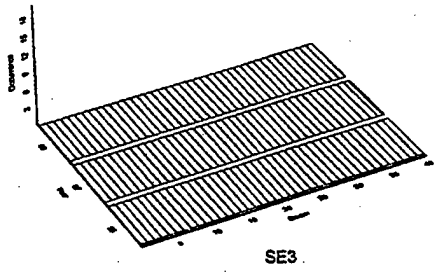
Occurrence of 'F' type fin whale calls in SE for August



SE1

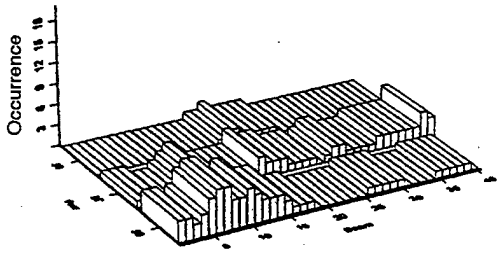


SE2

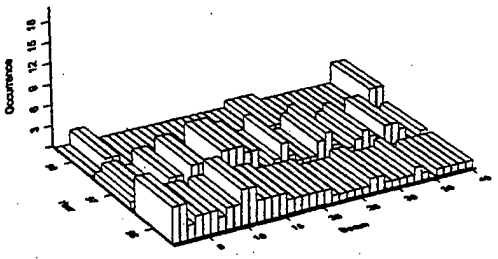


SE3

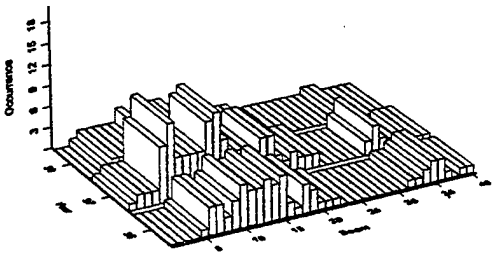
Occurrence of 'F' type fin whale calls in NE for September



NE1

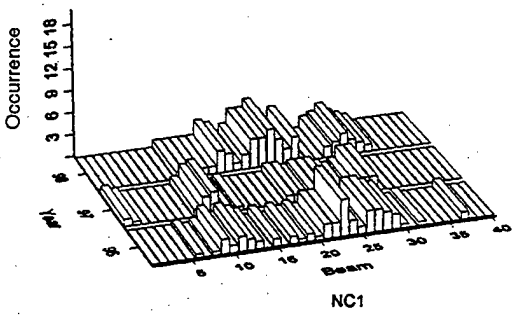


NE2

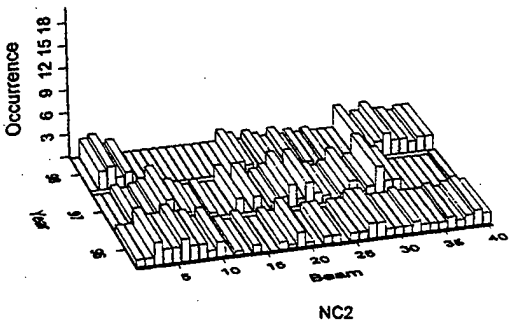


NE3

Occurrence of type 'F' fin whale calls in NC for September

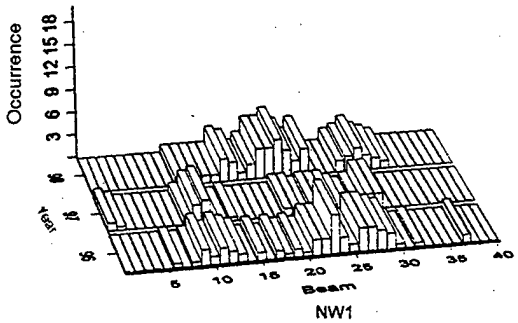


NC1

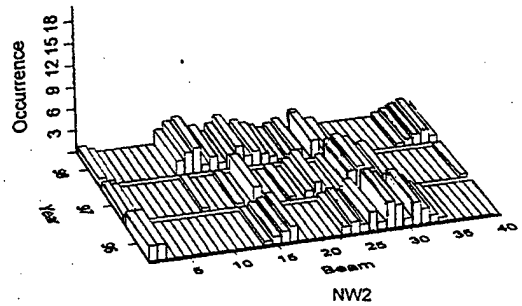


NC2

Occurrence of 'F' type fin whale calls in NW for September

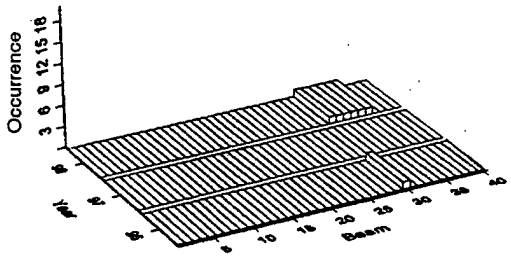


NW1

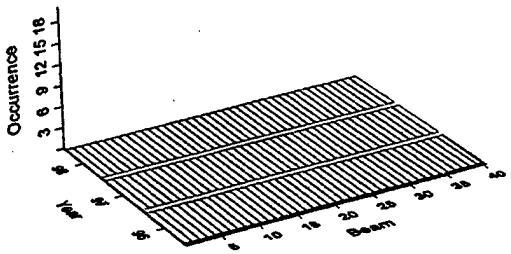


NW2

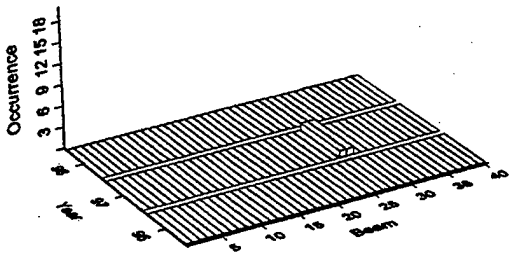
Occurrence of 'F' type fin whale calls in SE for September



SE1

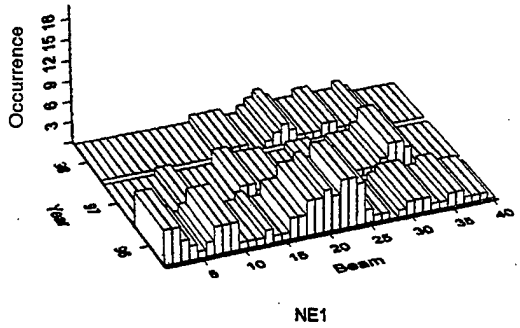


SE2

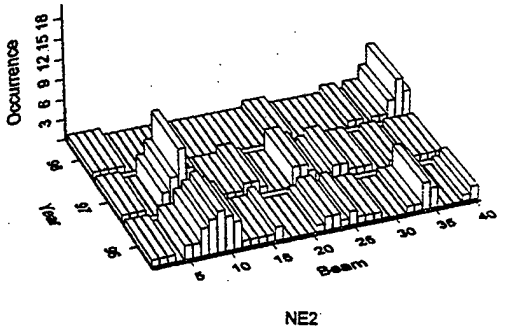


SE3

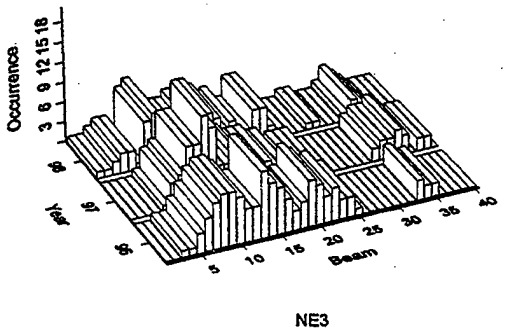
Occurrence of 'F' type fin whale calls in NE for October



NE1

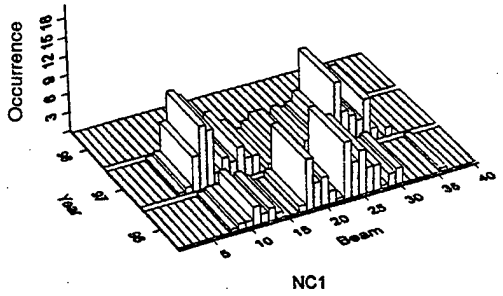


NE2

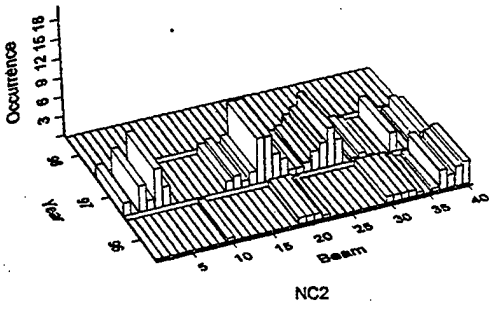


NE3

Occurrence of 'F' type fin whale calls in NC for October

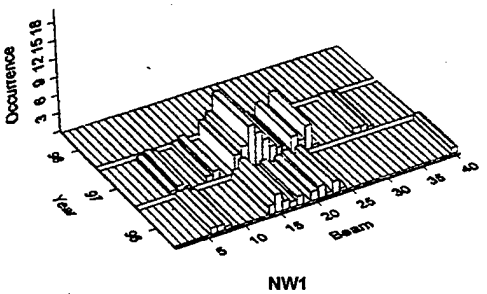


NC1

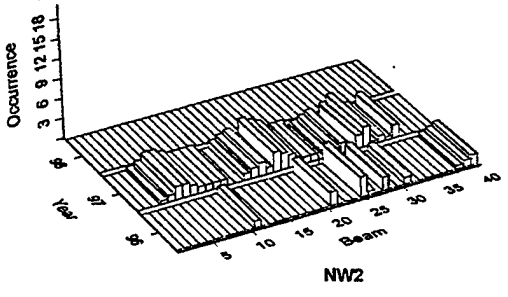


NC2

Occurrence of 'F' type fin whale calls in NW for October

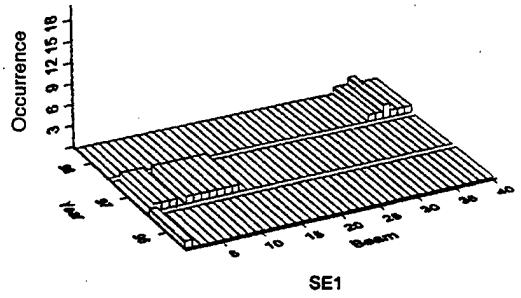


NW1

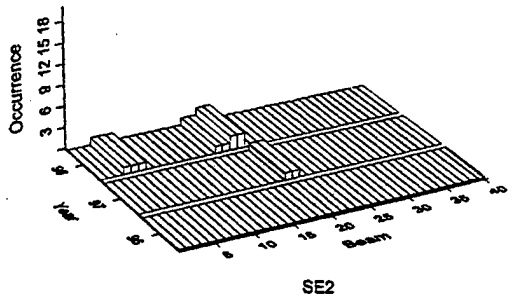


NW2

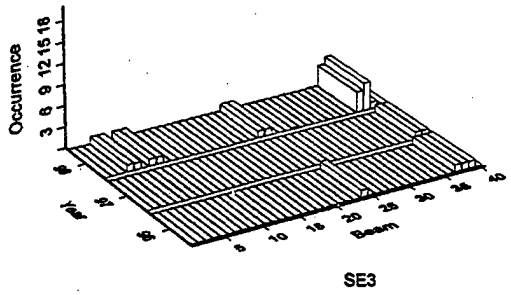
Occurrence of 'F' type fin whale calls in SE for October



SE1

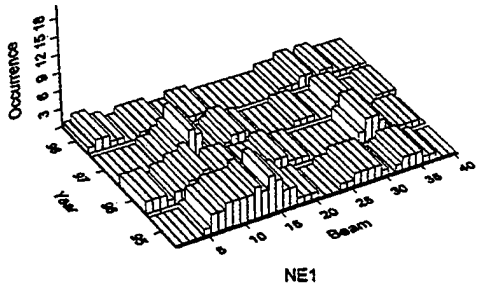


SE2

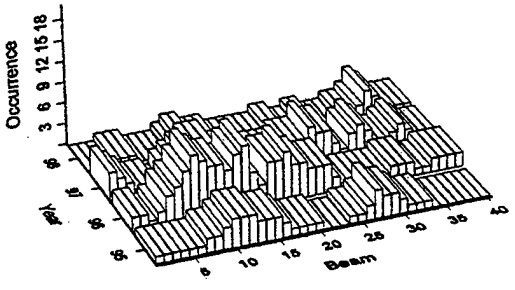


SE3

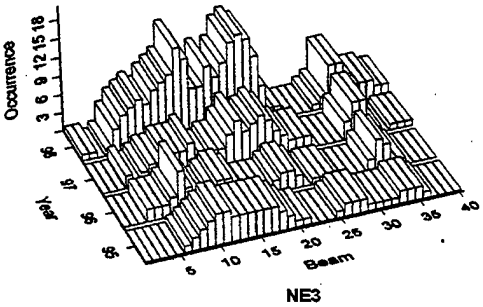
Occurrence of 'F' type fin whale calls in NE for November



NE1

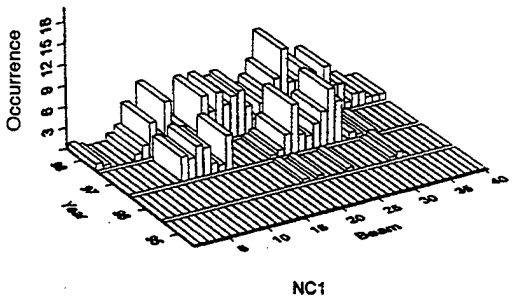


NE2

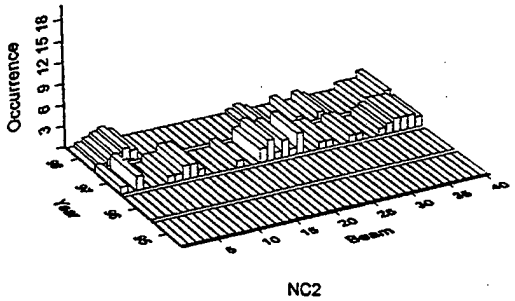


NE3

Occurrence of 'F' type calls in NC for November

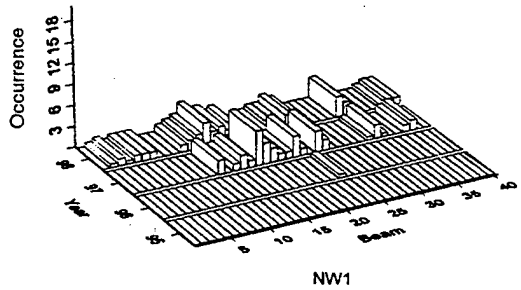


NC1

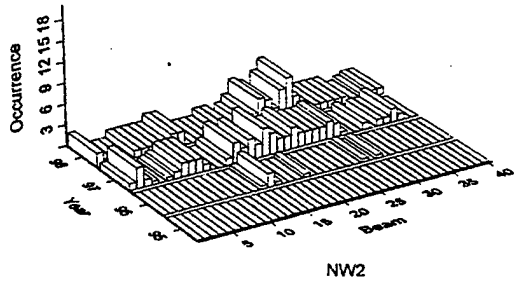


NC2

Occurrence of 'J' type calls in NW for November

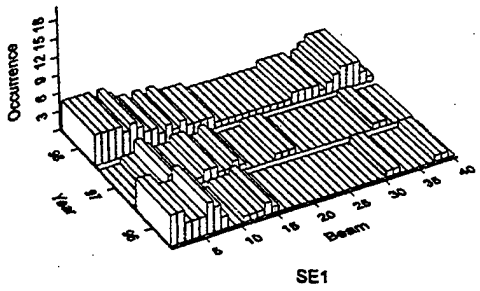


NW1

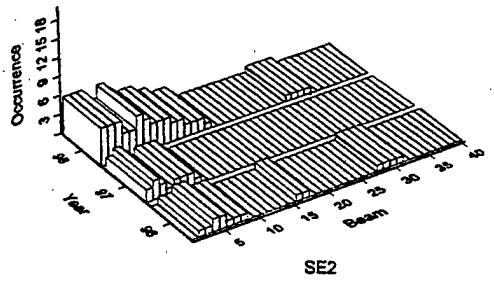


NW2

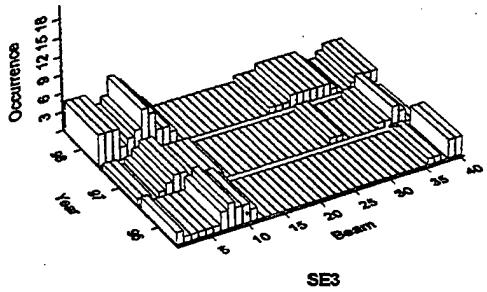
Occurrence of 'F' type fin whale calls in SE for November



SE1

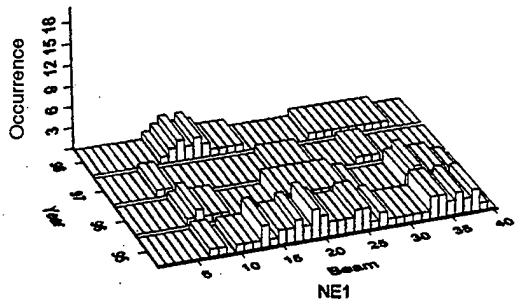


SE2

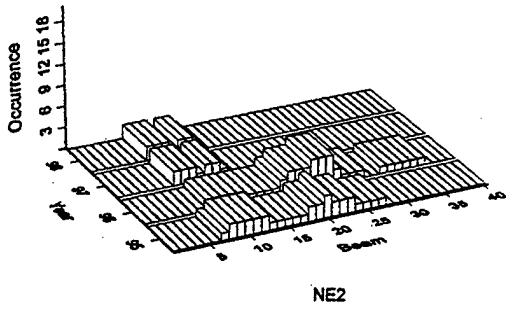


SE3

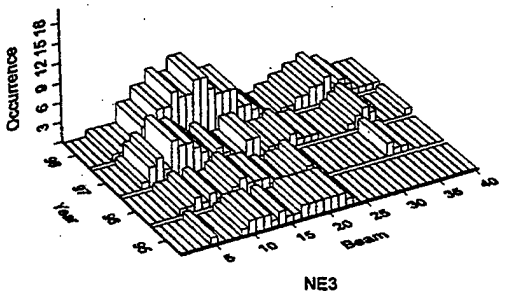
Occurrence of 'F' type fin whale calls in NE for December



NE1

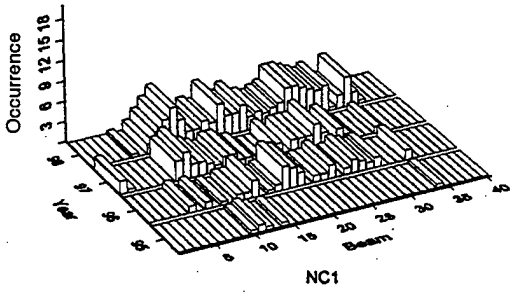


NE2

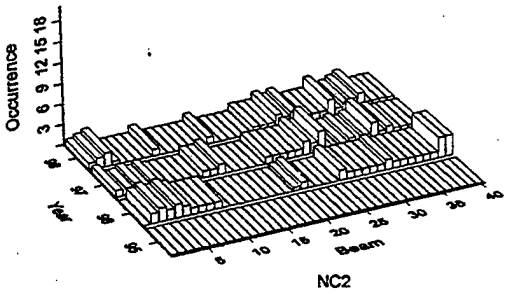


NE3

Occurrence of 'F' type fin whale calls in NC for December

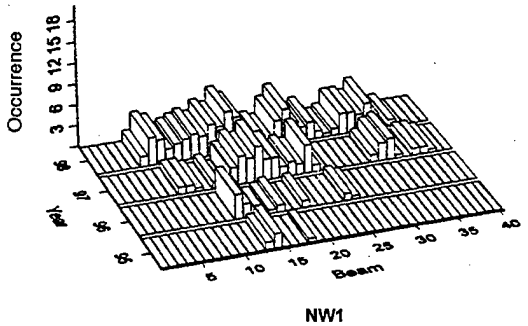


NC1

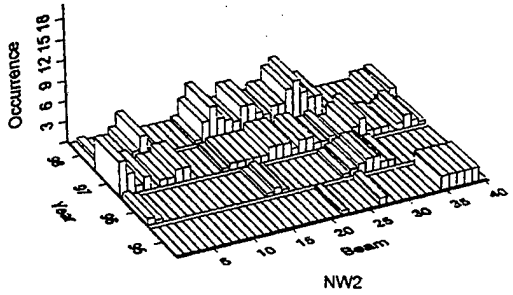


NC2

Occurrence of 'F' type fin whale calls in NW for December

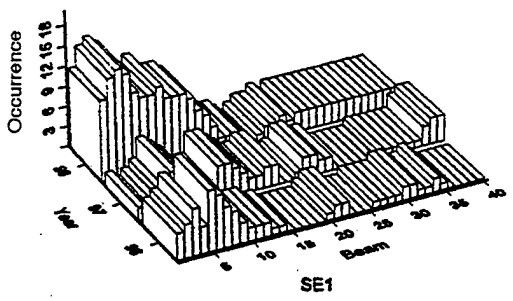


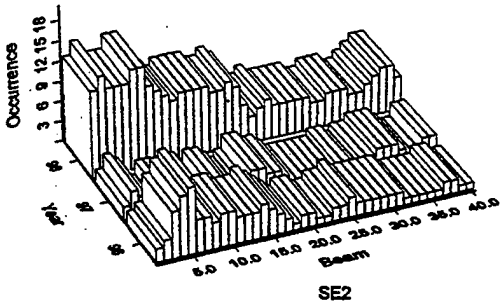
NW1

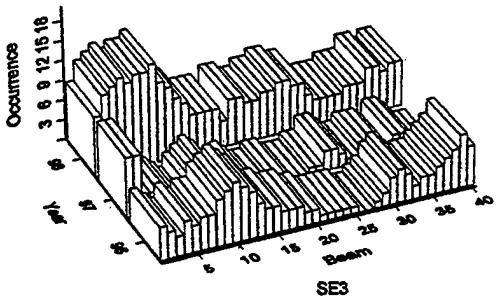


NW2

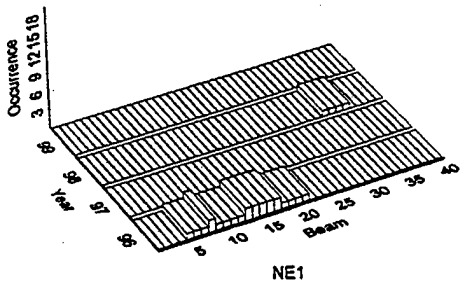
Occurrence of 'F' type fin whale calls in SE for December



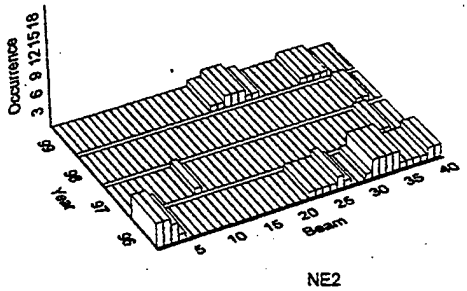




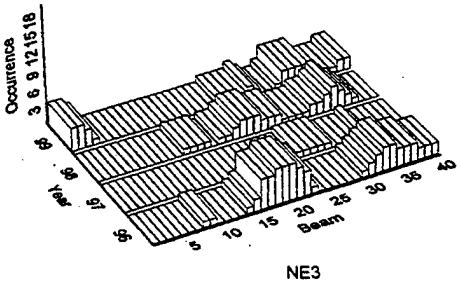
Occurrence of 'J' type fin whale calls in NE for January



NE1

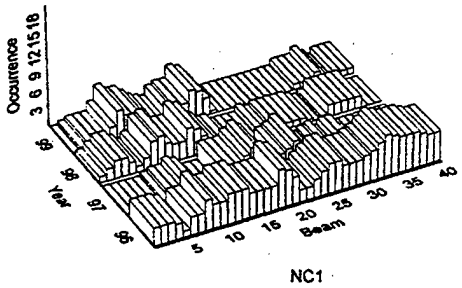


NE2

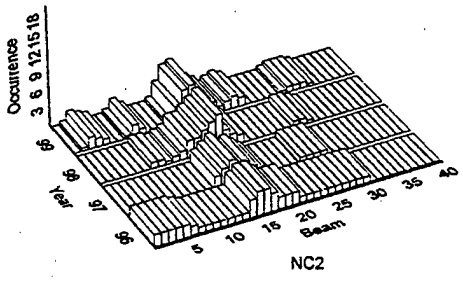


NE3

Occurrence of 'J' type fin whale calls in NC for January

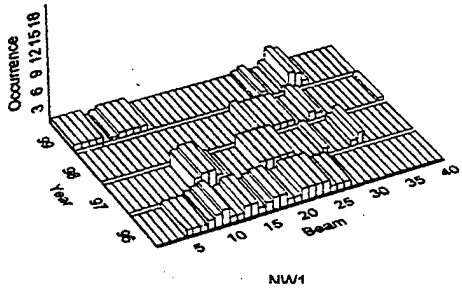


NC1

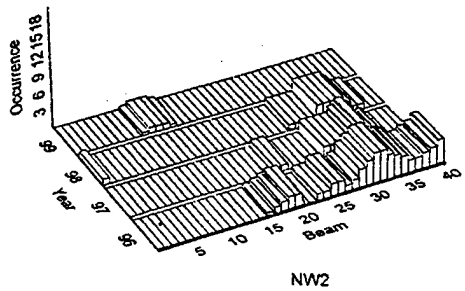


NC2

Occurrence of 'J' type fin whale calls in NW for January

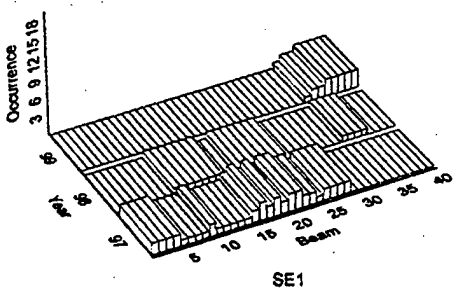


NW1

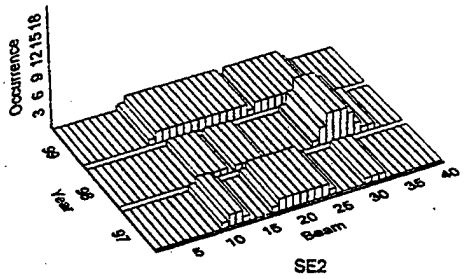


NW2

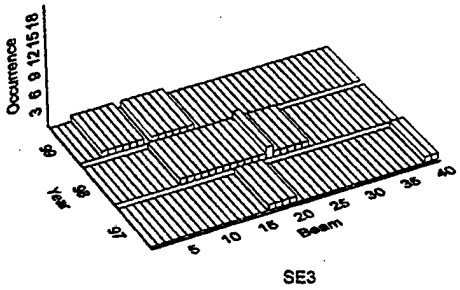
Occurrence of 'J' type fin whale calls in SE for January



SE1

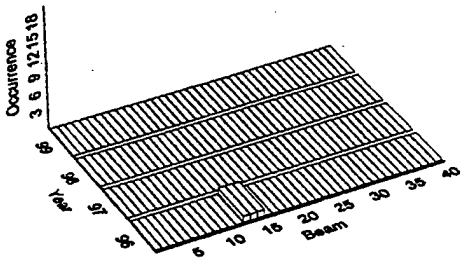


SE2

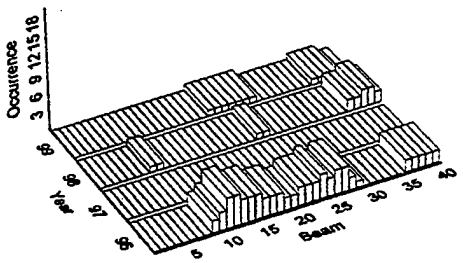


SE3

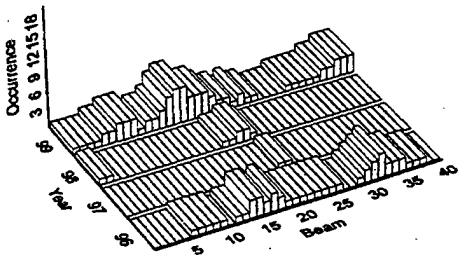
Occurrence of 'J' type fin whale calls in NE for February



NE1

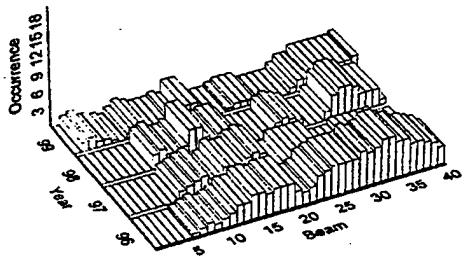


NE2

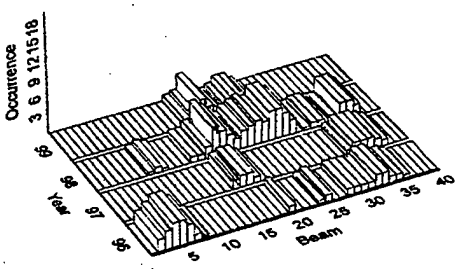


NE3

Occurrence of 'J' type fin whale calls in NC for February

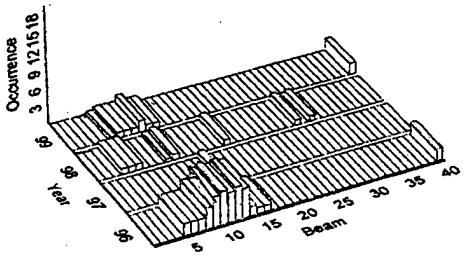


NC1

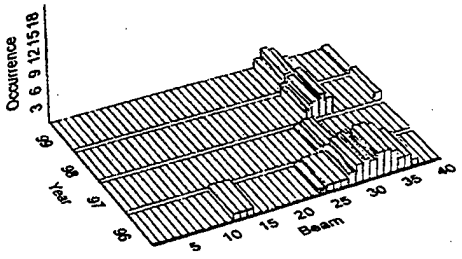


NC2

Occurrence of 'J' type fin whale calls in NW for February

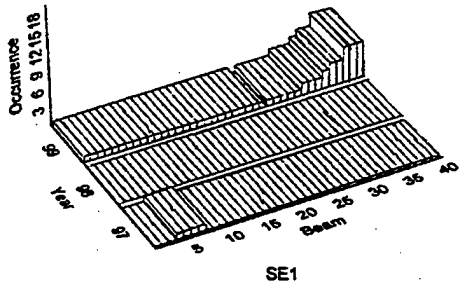


NW1

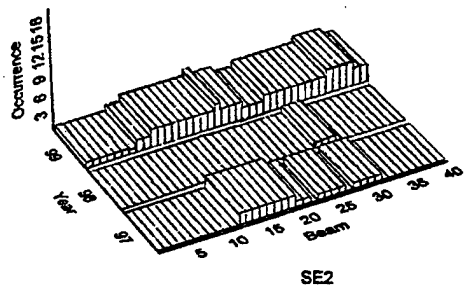


NW2

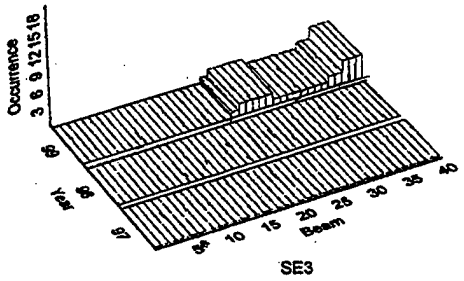
Occurrence of 'J' type fin whale calls in SE for February



SE1

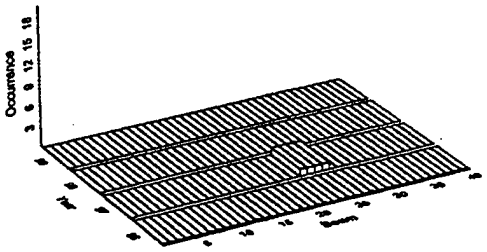


SE2

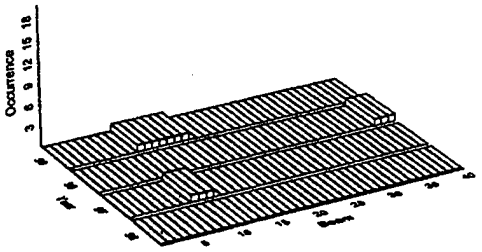


SE3

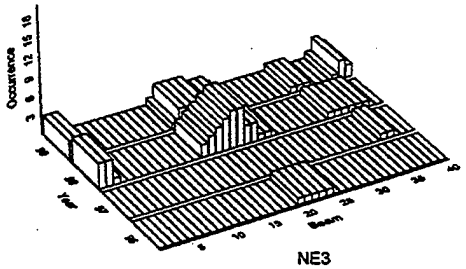
Occurrence of 'J' type fin whale calls in NE for March



NE1

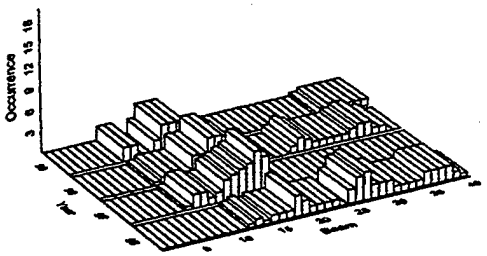


NE2

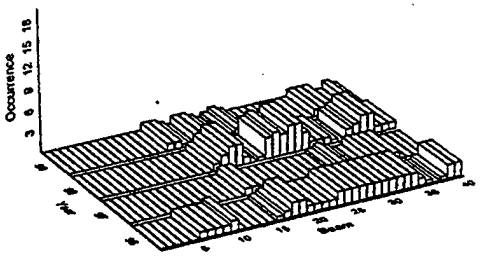


NE3

Occurrence of 'J' type fin whale calls in NC for March

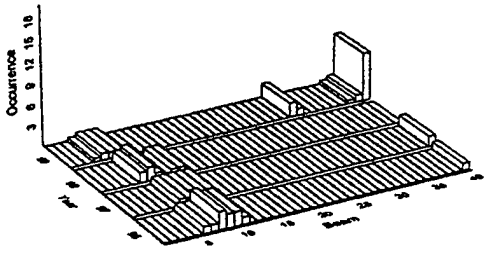


NC1

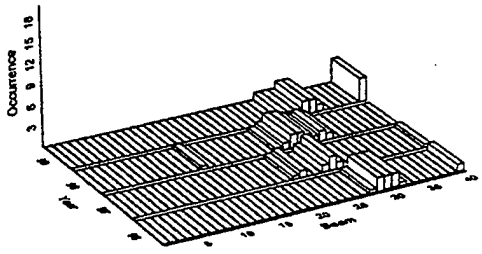


NC2

Occurrence of 'J' type fin whale calls in NW for March

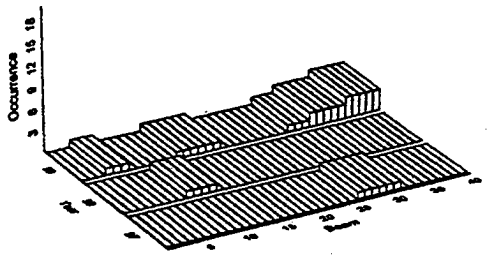


NW1

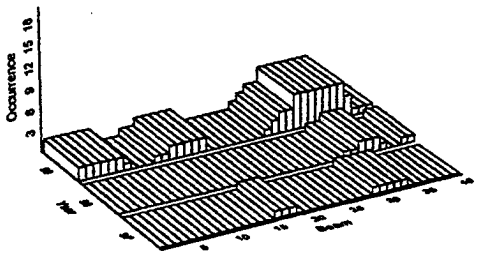


NW2

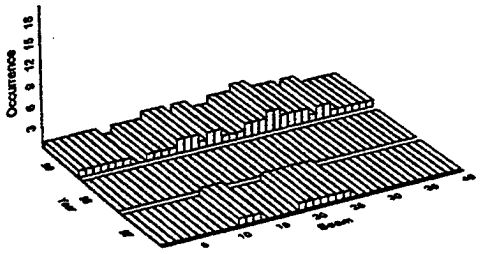
Occurrence of 'J' type fin whale calls in SE for March



SE1

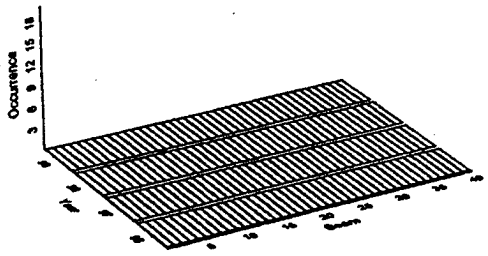


SE2

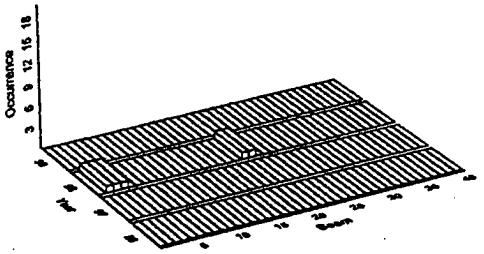


SE3

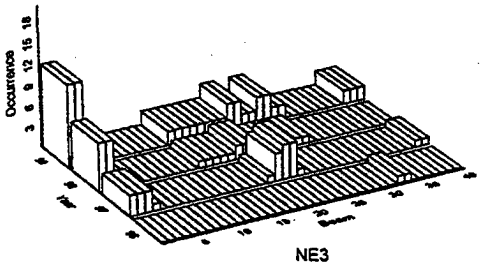
Occurrence of 'J' type fin whale calls in NE for April



NE1

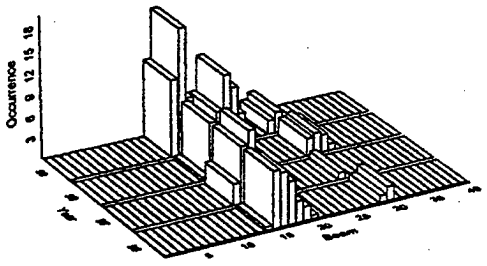


NE2

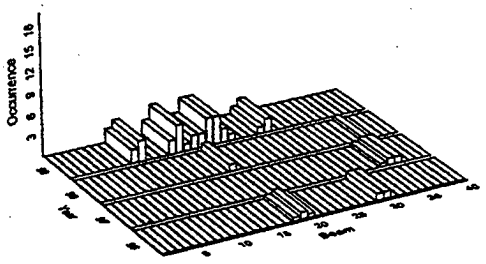


NE3

Occurrence of 'J' type fin whale calls in NC for April

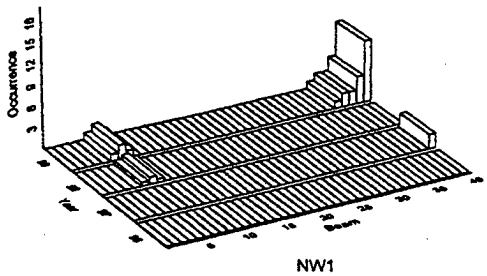


NC1

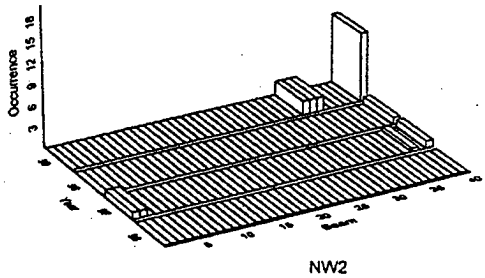


NC2

Occurrence of 'J' type fin whale calls in NW for April

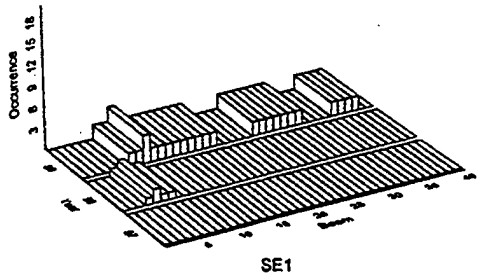


NW1

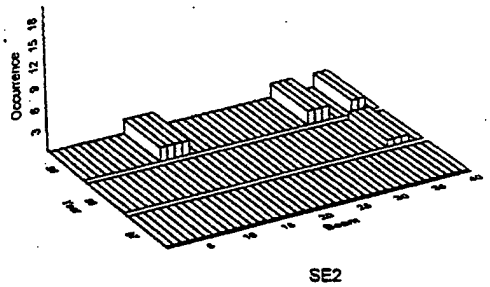


NW2

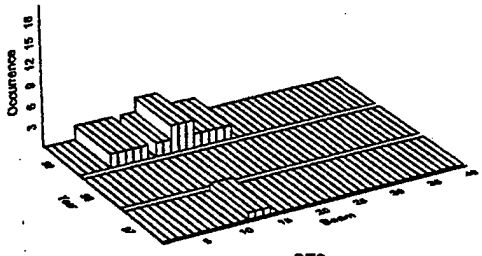
Occurrence of 'J' type fin whale calls in SE for April



SE1

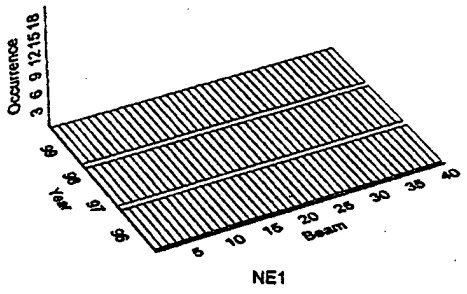


SE2

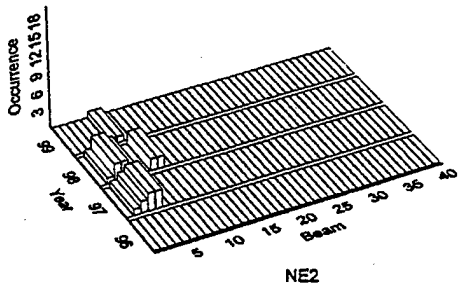


SE3

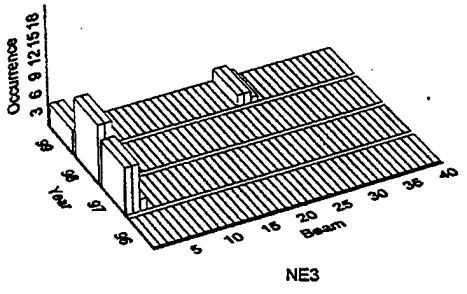
Occurrence of 'J' type fin whale calls in NE for May



NE1

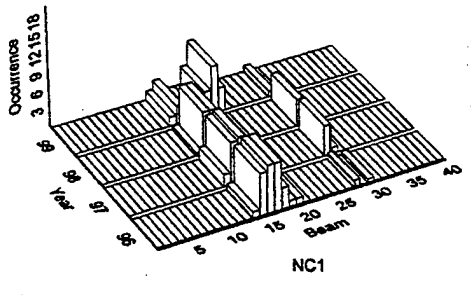


NE2

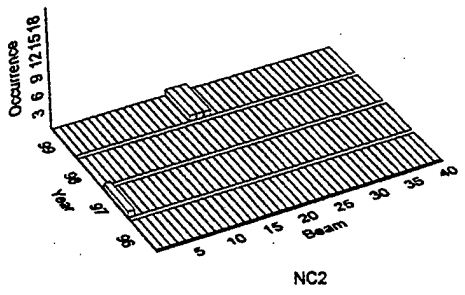


NE3

Occurrence of 'J' type fin whale calls in NC for May

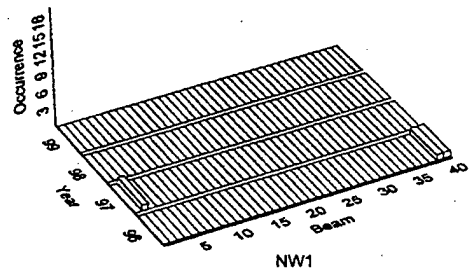


NC1

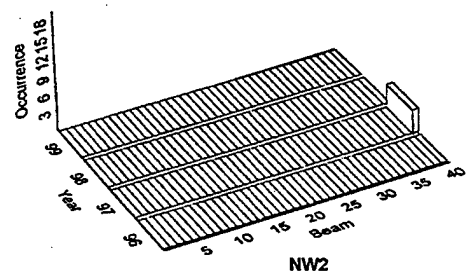


NC2

Occurrence of 'J' type fin whale calls in NW for May

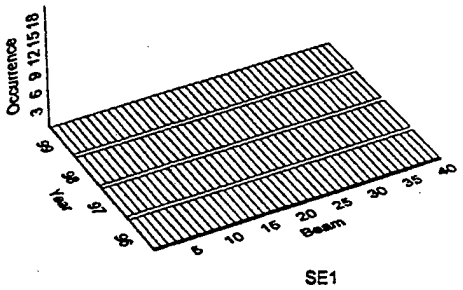


NW1

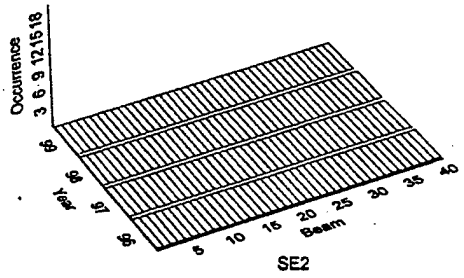


NW2

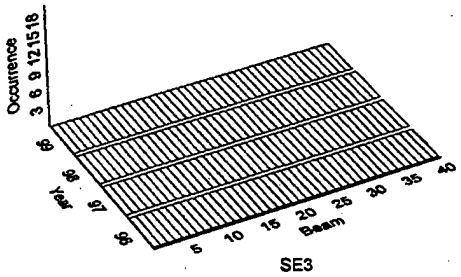
Occurrence of 'J' type fin whale calls in SE for May



SE1

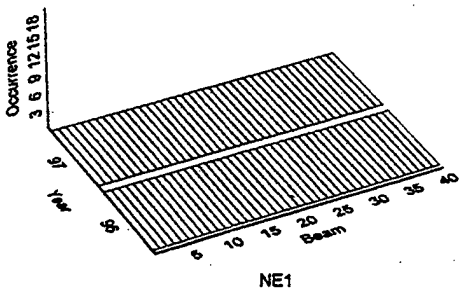


SE2

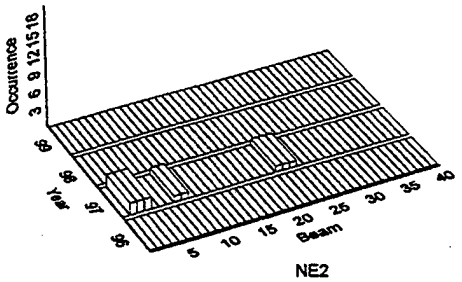


SE3

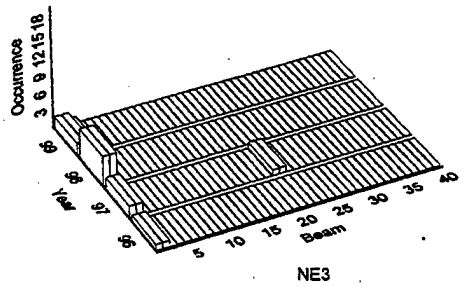
Occurrence of 'J' type fin whale calls in NE for June



NE1

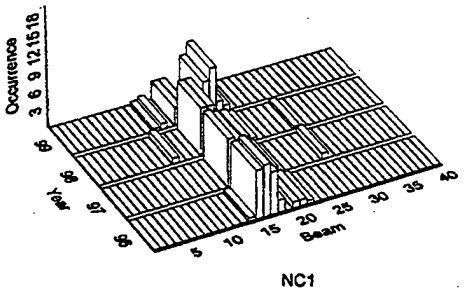


NE2

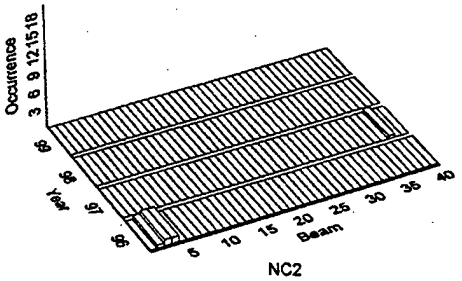


NE3

Occurrence of 'J' type fin whale calls in NC for June

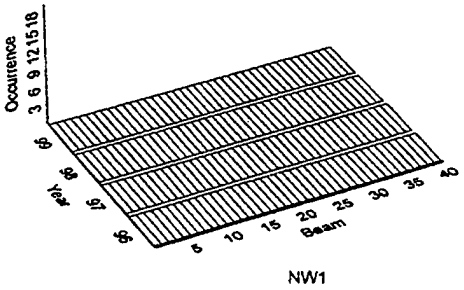


NC1

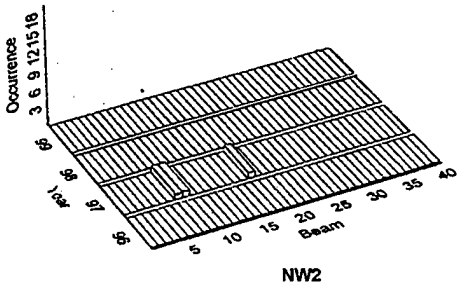


NC2

Occurrence of 'J' type fin whale calls in NW for June

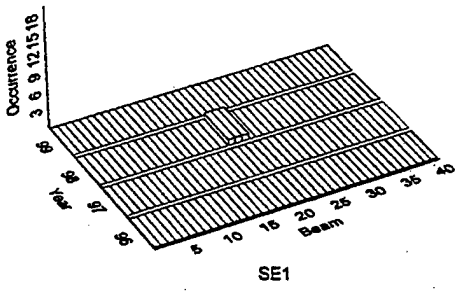


NW1

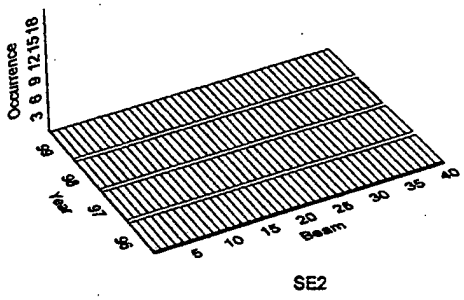


NW2

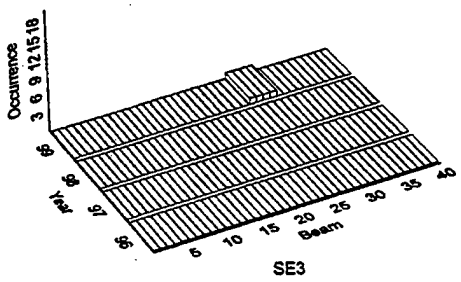
Occurrence of 'J' type fin whale calls in SE for June
**No data was taken in 1998



SE1

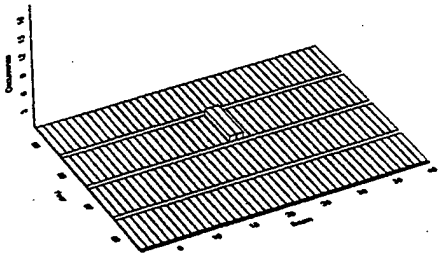


SE2

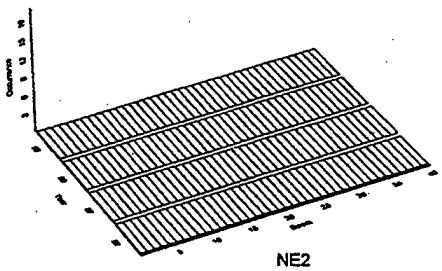


SE3

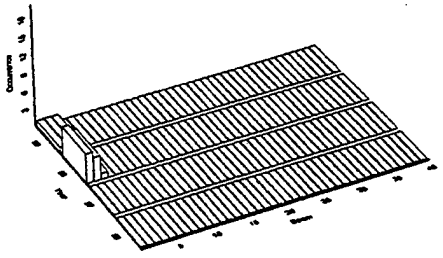
Occurrence of 'J' type fin whale calls in NE for July



NE1

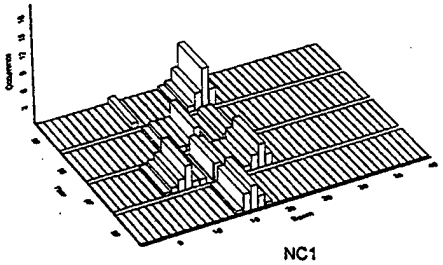


NE2

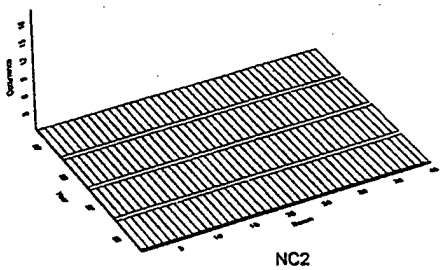


NE3

Occurrence of 'J' type fin whale calls in NC for July

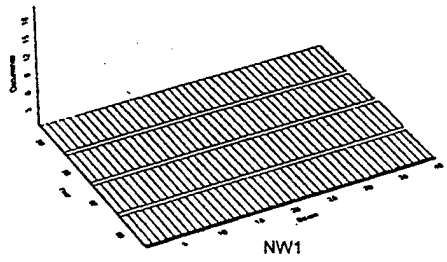


NC1

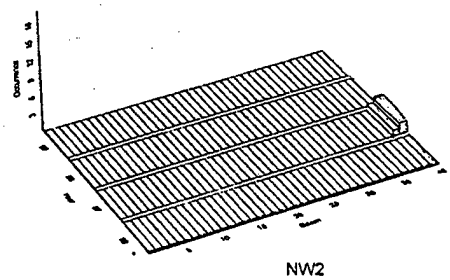


NC2

Occurrence of 'J' type fin whale calls in NW for July

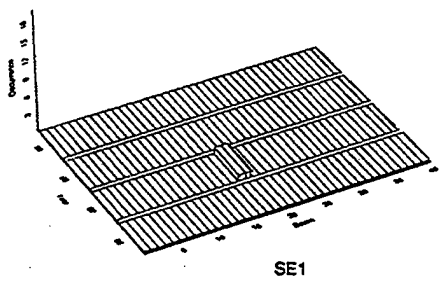


NW1

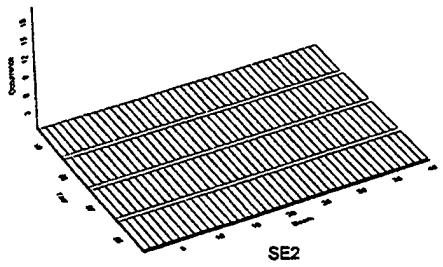


NW2

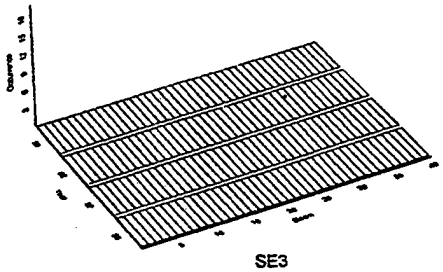
Occurrence of 'J' type fin whale calls in SE for July



SE1

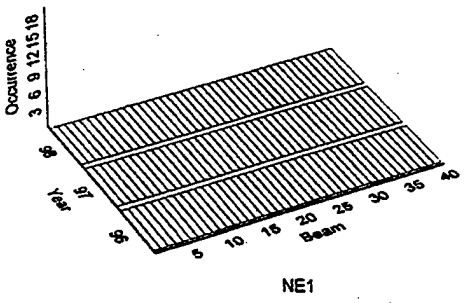


SE2

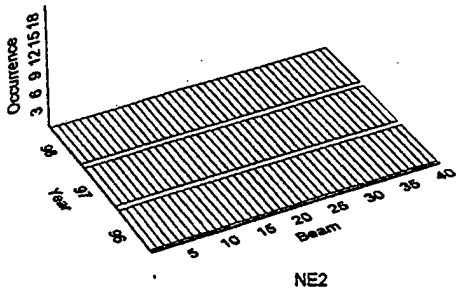


SE3

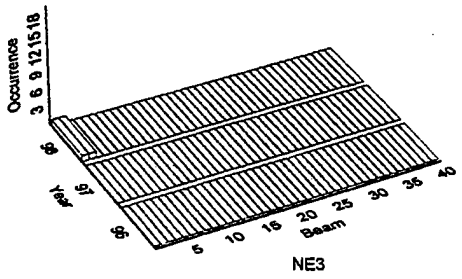
Occurrence of 'J' type fin whale calls in NE for August



NE1

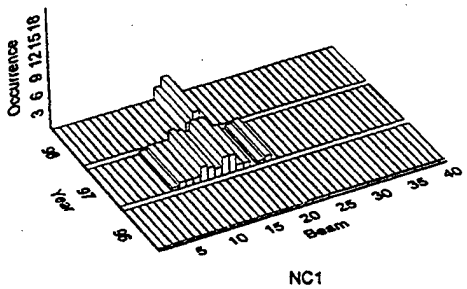


NE2

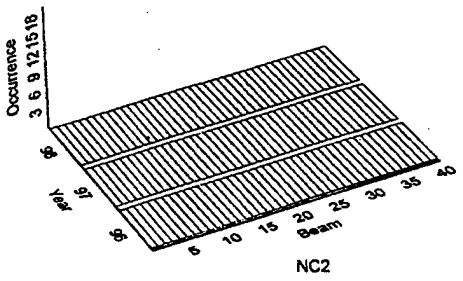


NE3

Occurrence of 'J' type fin whale calls in NC for August

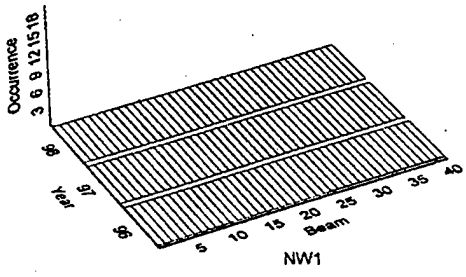


NC1

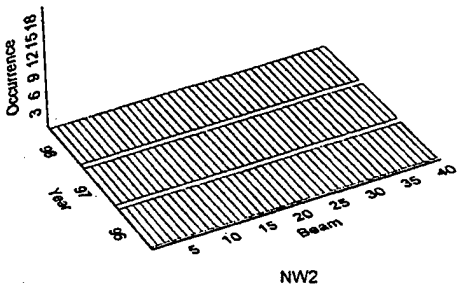


NC2

Occurrence of 'J' type fin whale calls in NW for August

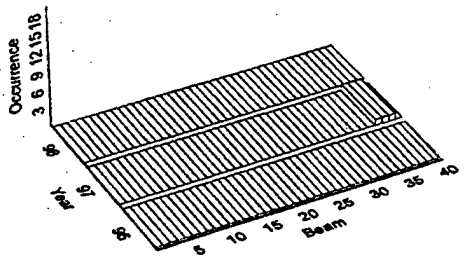


NW1

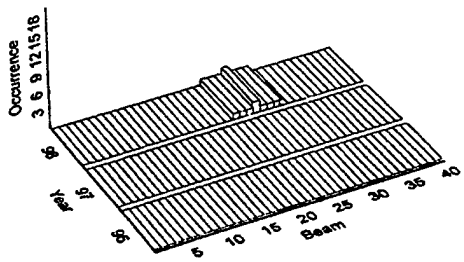


NW2

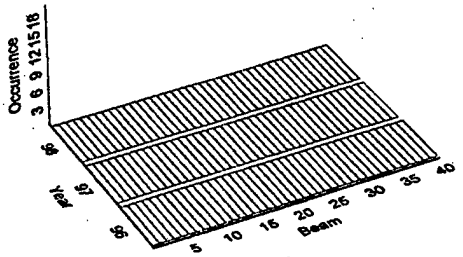
Occurrence of 'J' type fin whale calls in SE for August



SE1

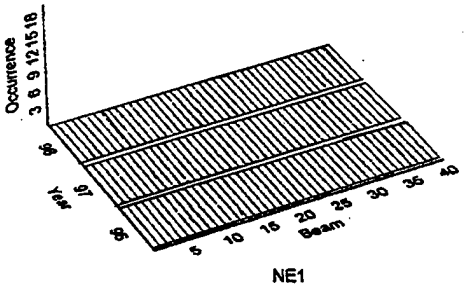


SE2

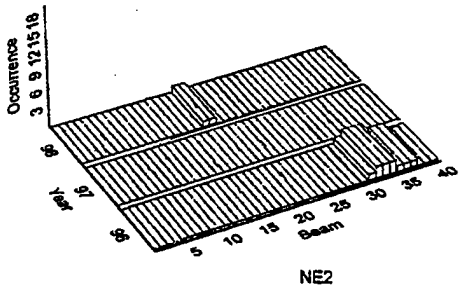


SE3

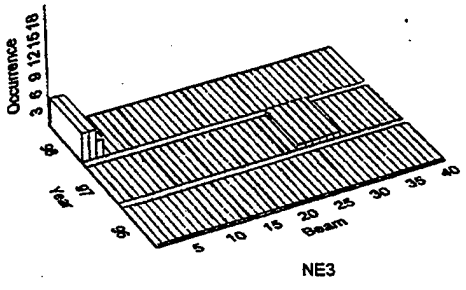
Occurrence of 'J' type fin whale calls in NE for September



NE1

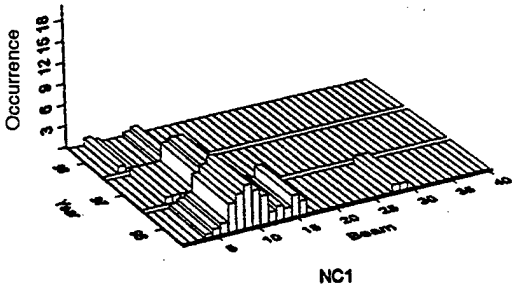


NE2

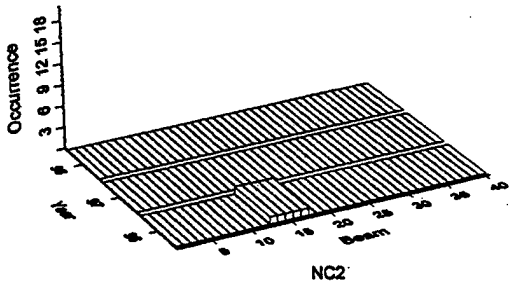


NE3

Occurrence of 'J' type calls in NC for September

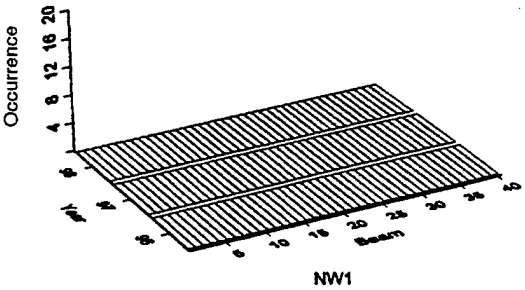


NC1

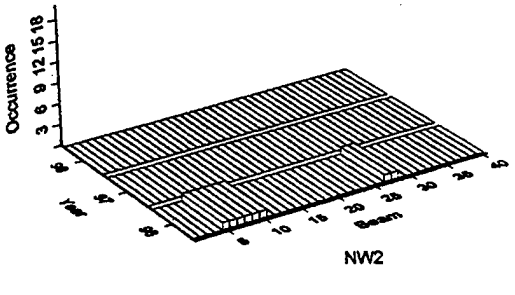


NC2

Occurrence of 'J' type calls in NW for September

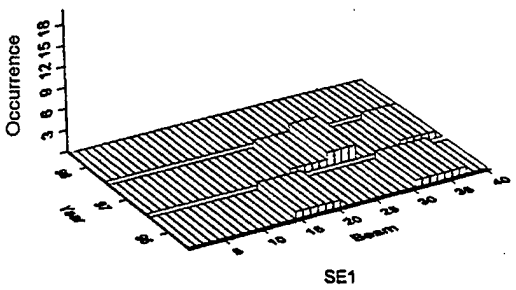


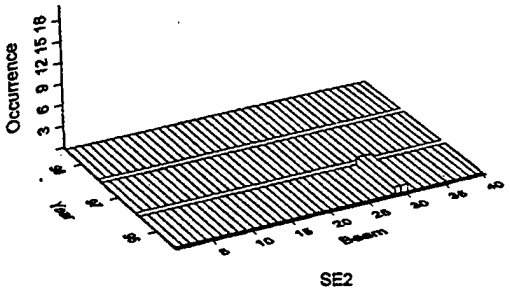
NW1

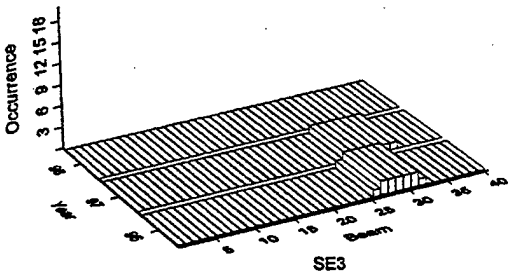


NW2

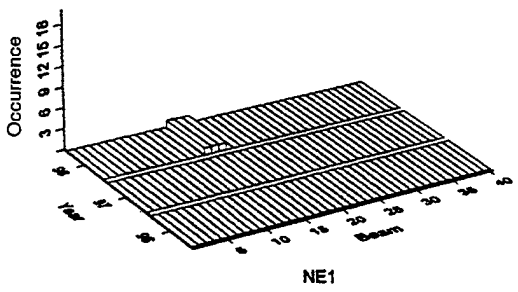
Occurrence of 'J' type calls in SE for September



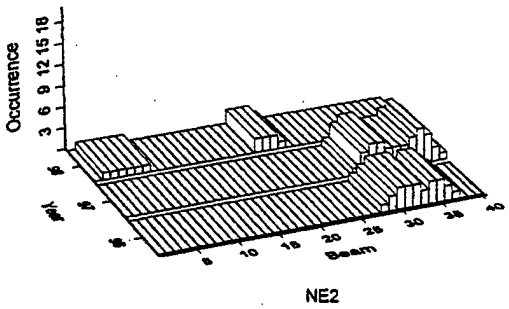




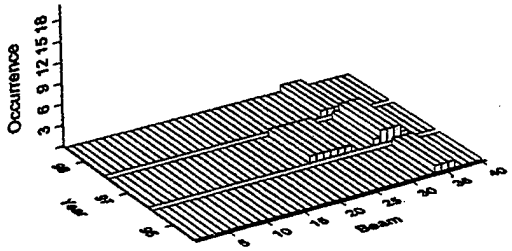
Occurrence of 'J' type fin whale calls in NE for October



NE1

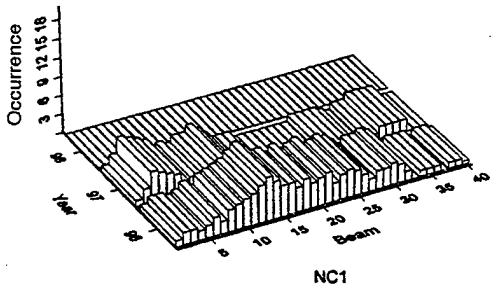


NE2

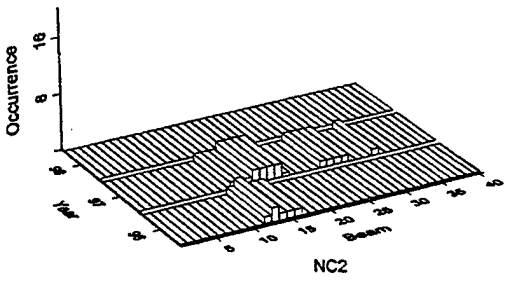


NE3

Occurrence of 'J' type fin whale calls in NC for October

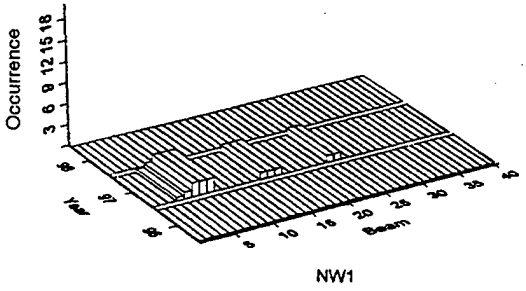


NC1

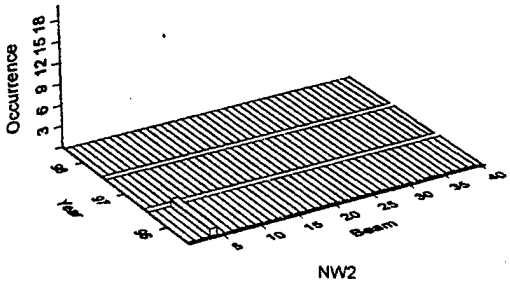


NC2

Occurrence of 'J' type fin whale calls in NW for October

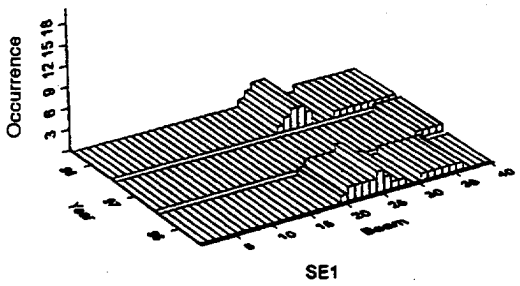


NW1

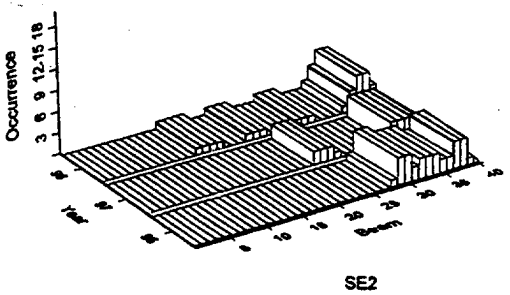


NW2

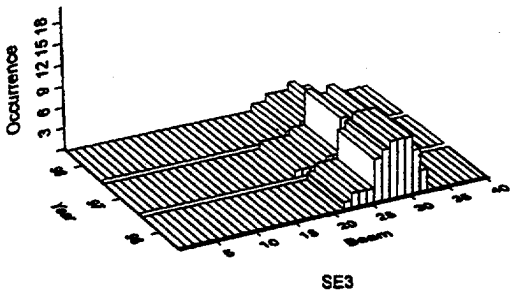
Occurrence of 'J' type fin whale calls in SE for October



SE1

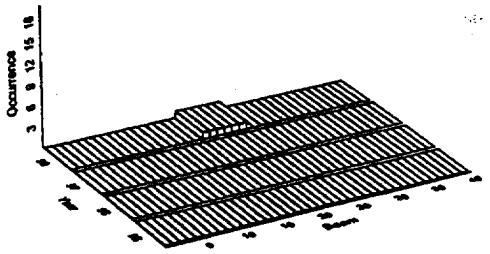


SE2

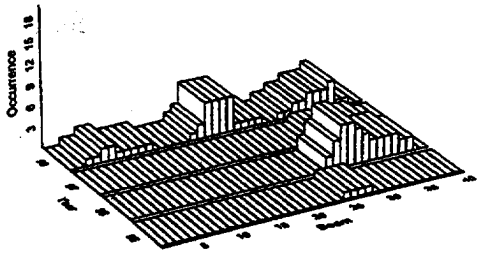


SE3

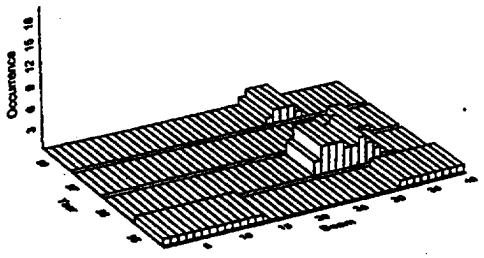
Occurrence of 'J' type fin whale calls in NE for November



NE1

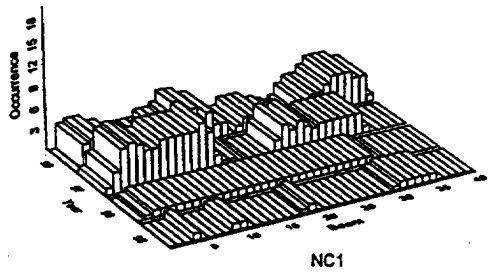


NE2

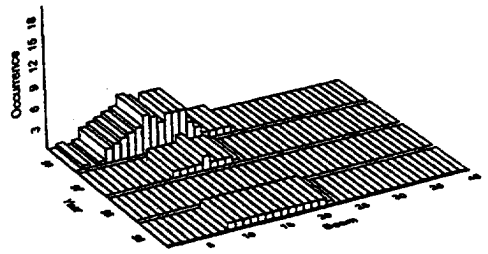


NE3

Occurrence of 'J' type fin whale calls in NC for November

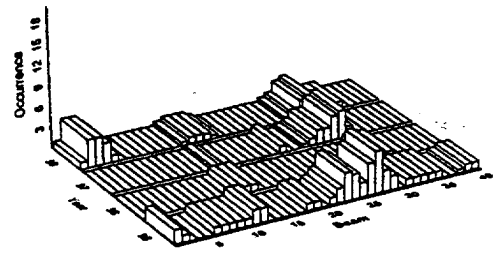


NC1

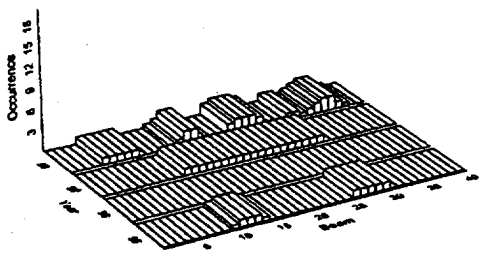


NC2

Occurrence of 'J' type fin whale calls in NW for November

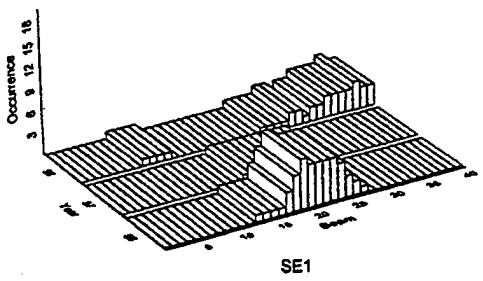


NW1

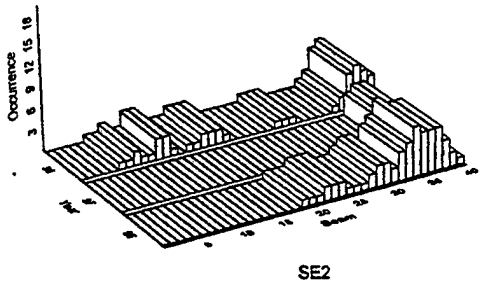


NW2

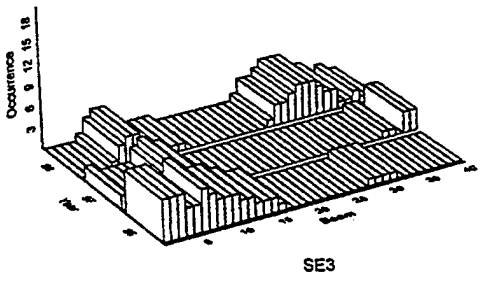
Occurrence of 'J' type fin whale calls in SE for November



SE1

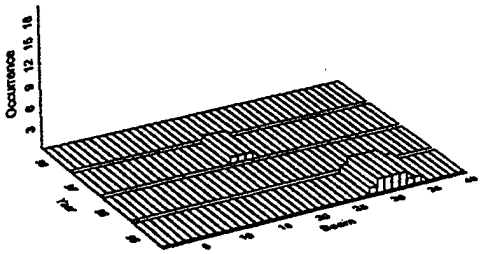


SE2

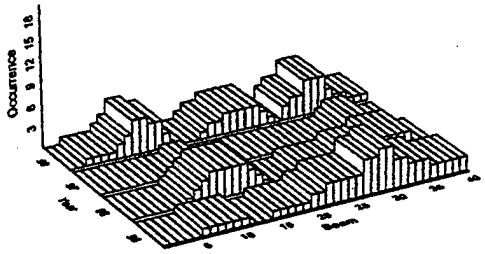


SE3

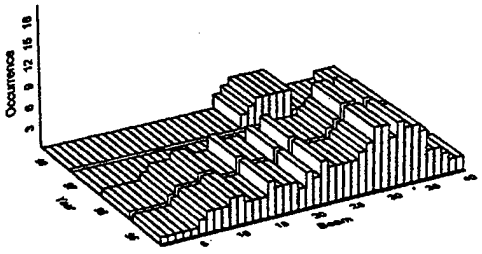
Occurrence of 'J' type fin whale calls in NE for December



NE1

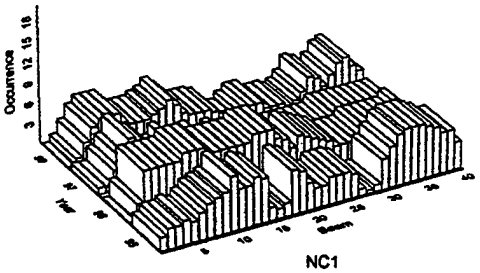


NE2

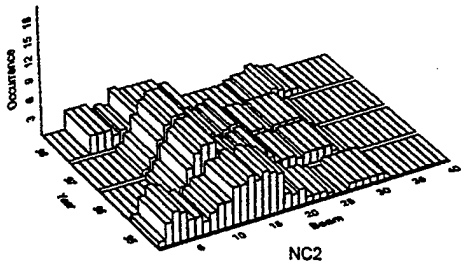


NE3

Occurrence of 'J' type fin whale calls in NC for December

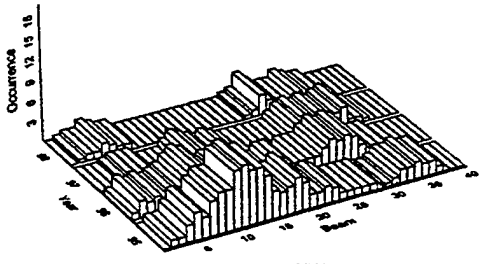


NC1

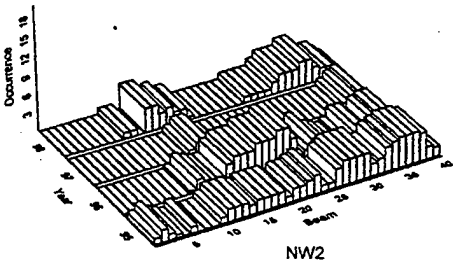


NC2

Occurrence of 'J' type fin whale calls in NW for December

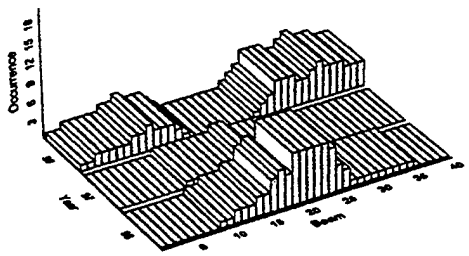


NW1

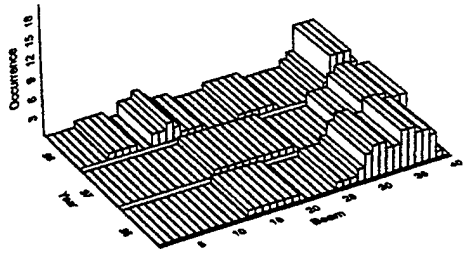


NW2

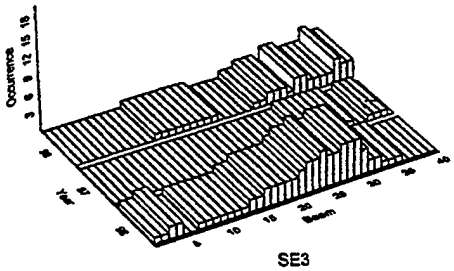
Occurrence of 'J' type fin whale calls in SE for December



SE1

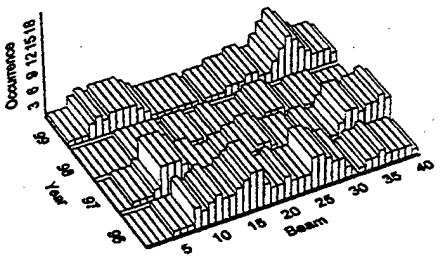


SE2

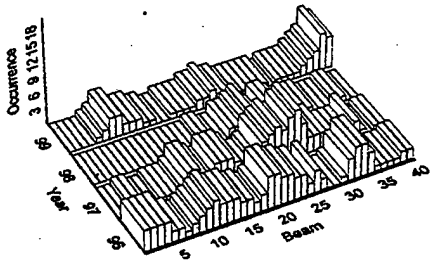


SE3

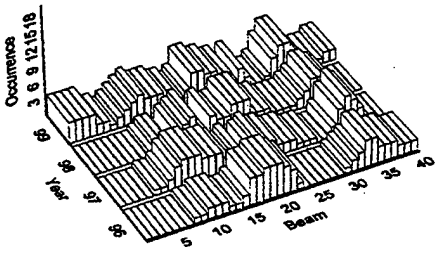
Occurrence of 'F' and 'J' type fin whale calls in NE for January



NE1

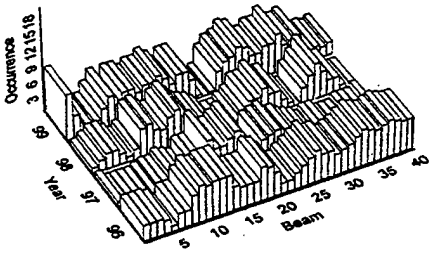


NE2

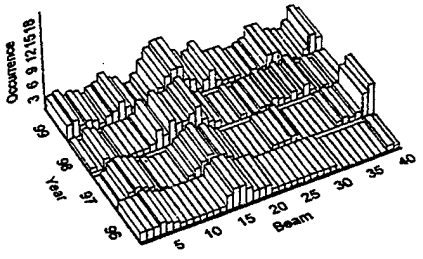


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for January

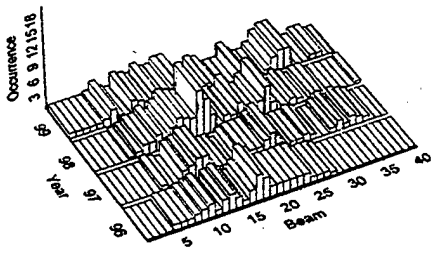


NC1

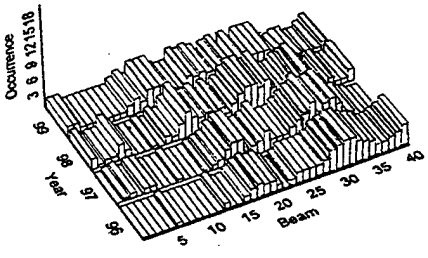


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for January

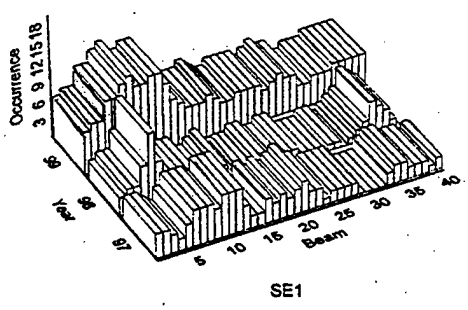


NW1

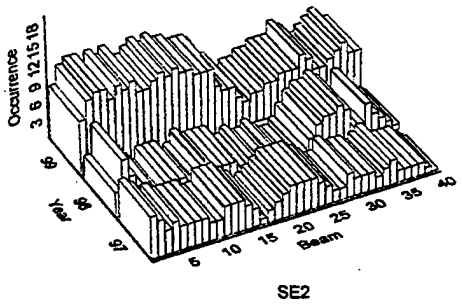


NW2

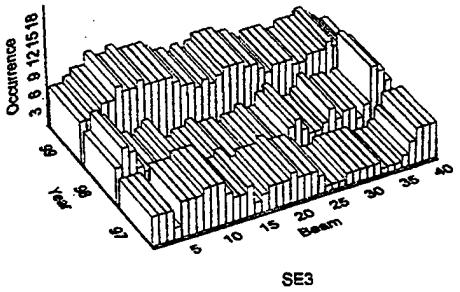
Occurrence of 'F' and 'J' type fin whale calls in SE for January



SE1

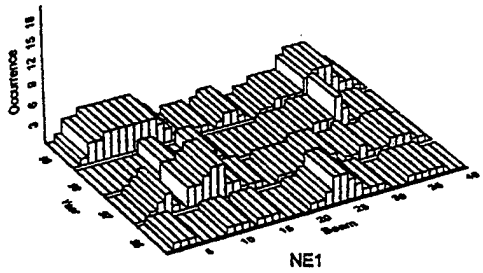


SE2

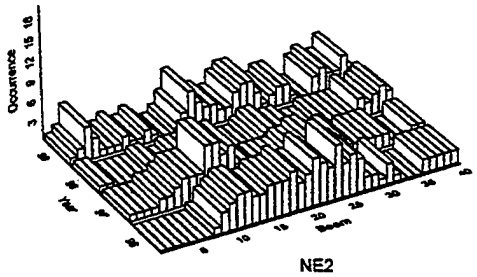


SE3

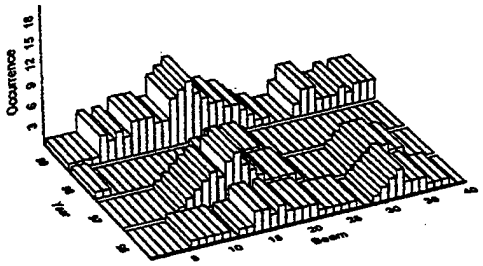
Occurrence of 'F' and 'J' type fin whale calls in NE for February



NE1

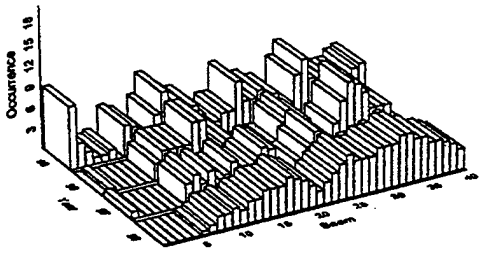


NE2

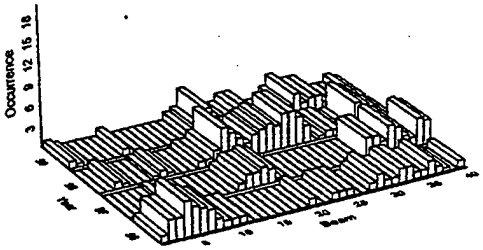


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for February

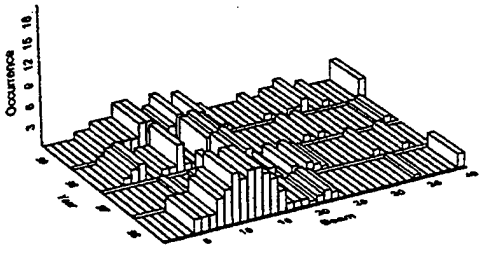


NC1

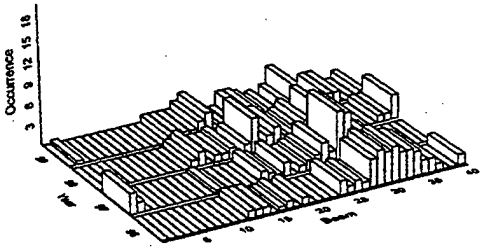


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for February

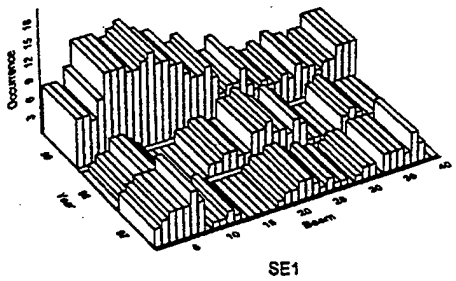


NW1

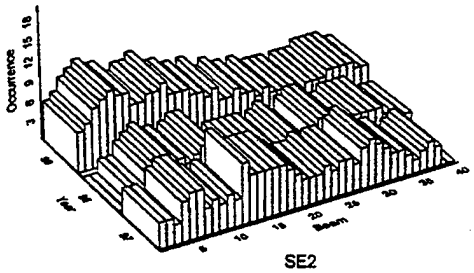


NW2

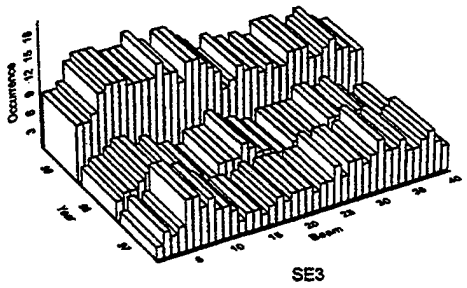
Occurrence of 'F' and 'J' type fin whale calls in SE for February



SE1

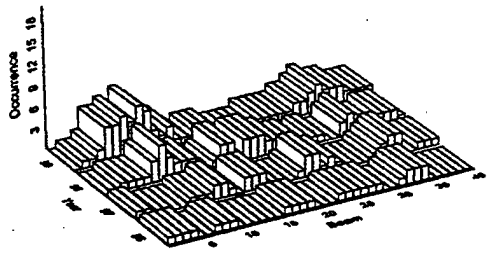


SE2

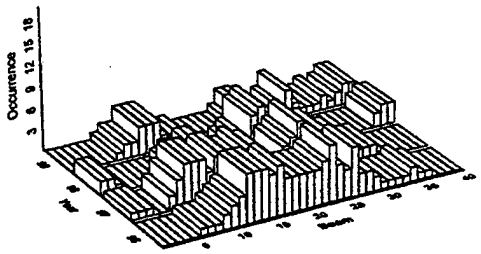


SE3

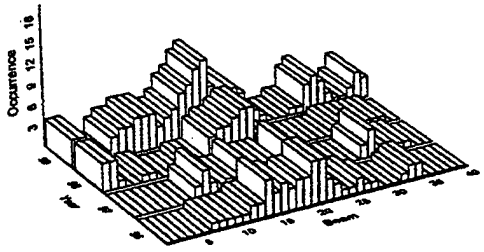
Occurrence of 'F' and 'J' type fin whale calls in NE for March



NE1

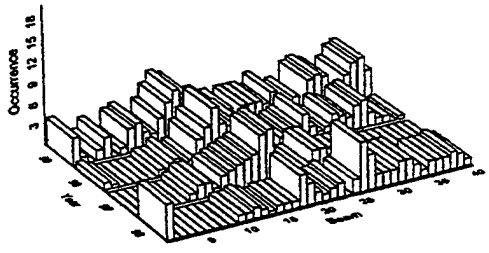


NE2

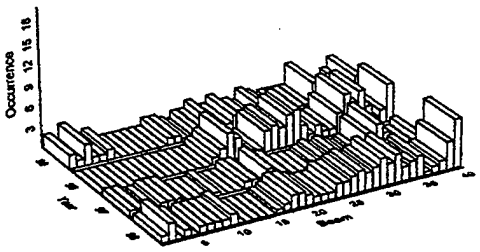


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for March

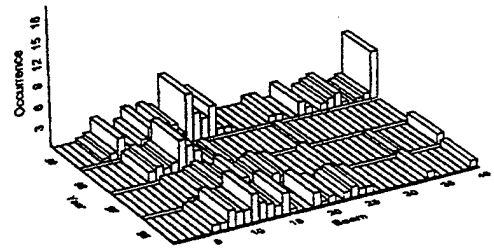


NC1

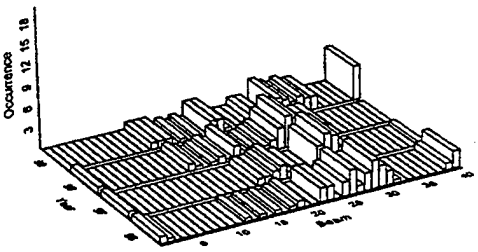


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for March

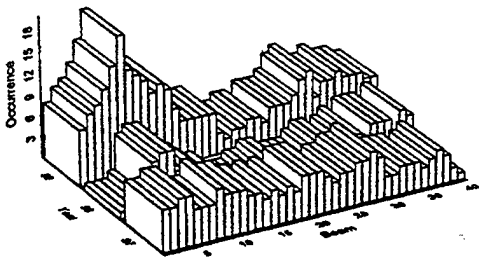


NW1

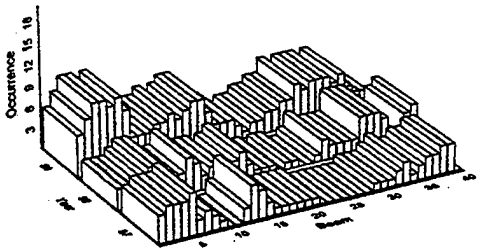


NW2

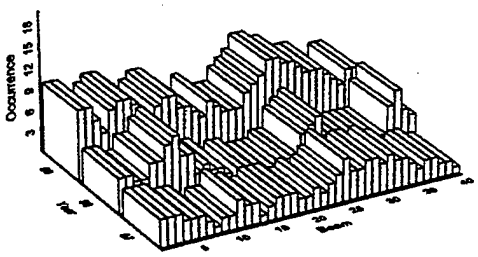
Occurrence of 'F' and 'J' type fin whale calls in SE for March



SE1

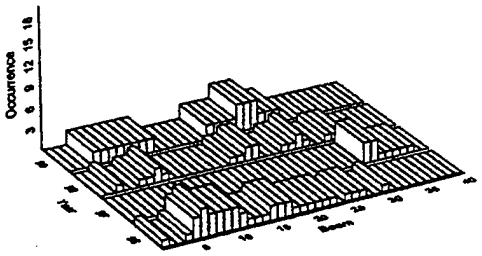


SE2

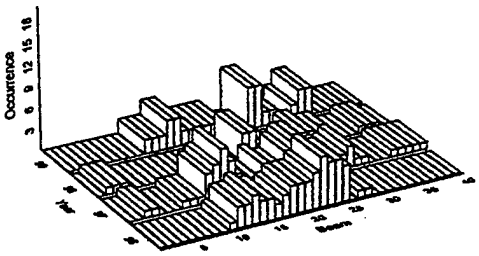


SE3

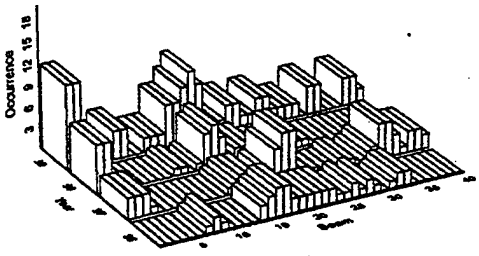
Occurrence of 'F' and 'J' type fin whale calls in NE for April



NE1

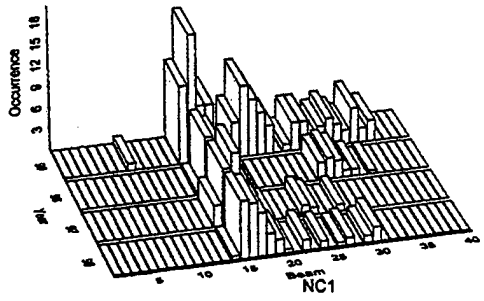


NE2

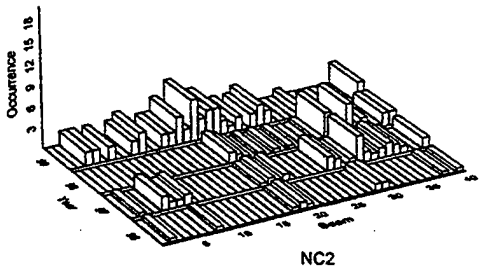


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for April

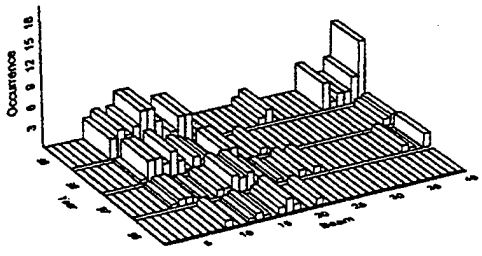


NC1

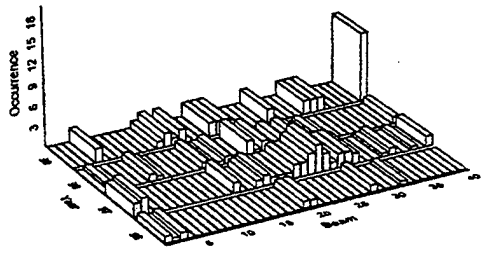


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for April

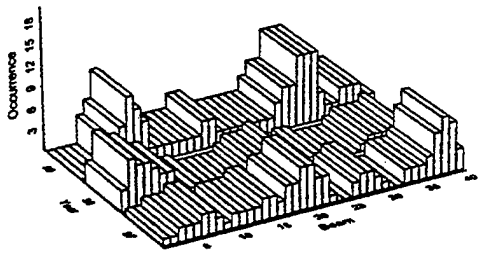


NW1

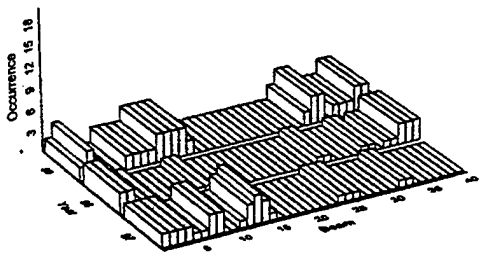


NW2

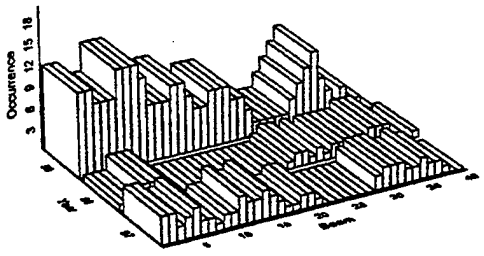
Occurrence of 'F' and 'J' type fin whale calls in SE for April



SE1

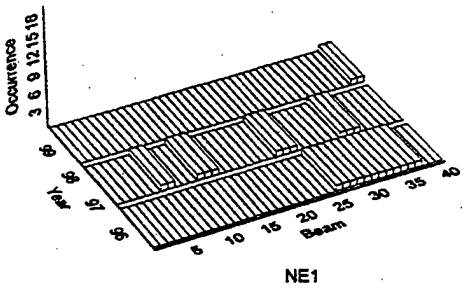


SE2

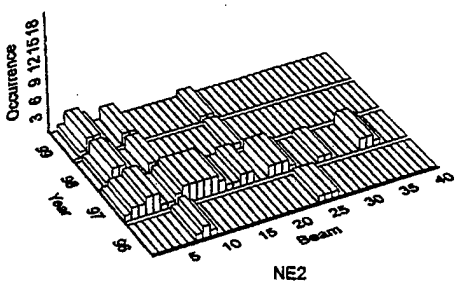


SE3

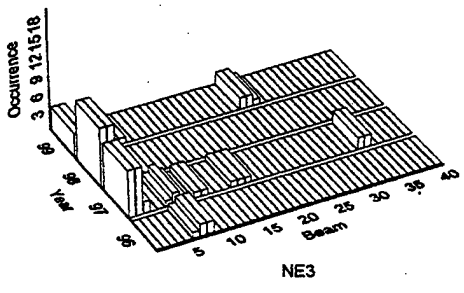
Occurrence of 'F' and 'J' type fin whale calls in NE for May



NE1

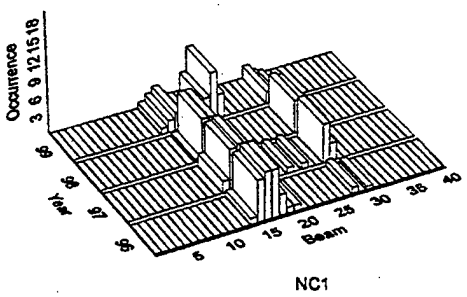


NE2

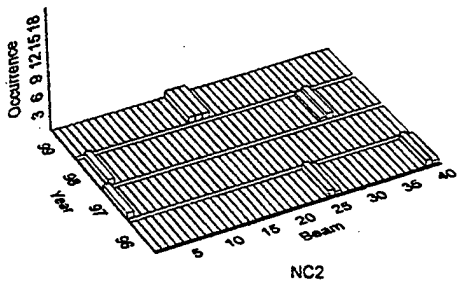


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for May

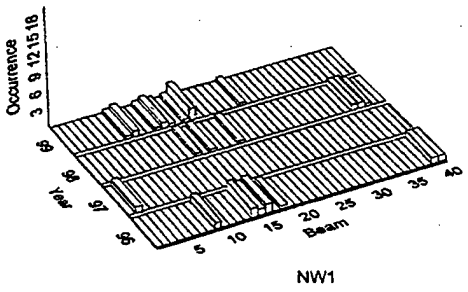


NC1

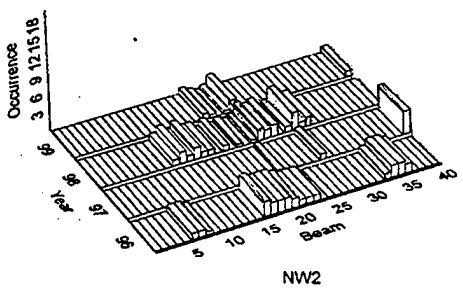


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for May

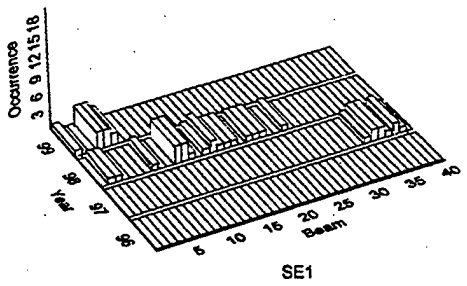


NW1

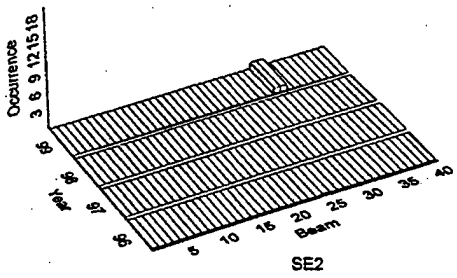


NW2

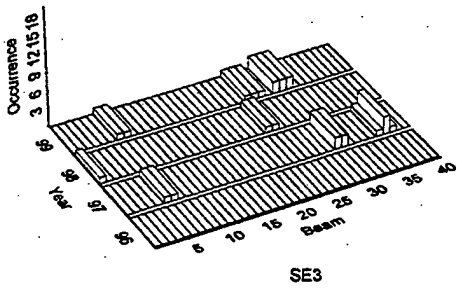
Occurrence of F and J type fin whale calls in SE for May



SE1

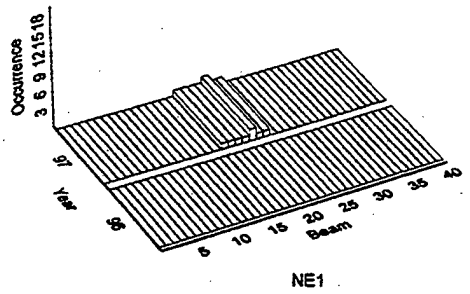


SE2

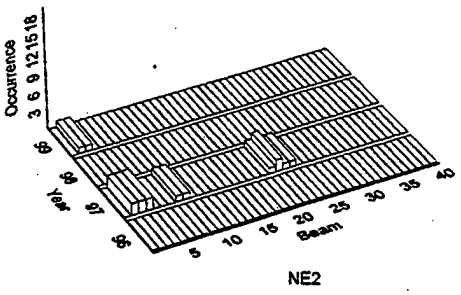


SE3

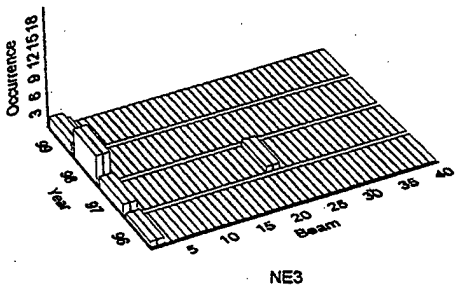
Occurrence of 'F' and 'J' type fin whale calls in NE for June



NE1

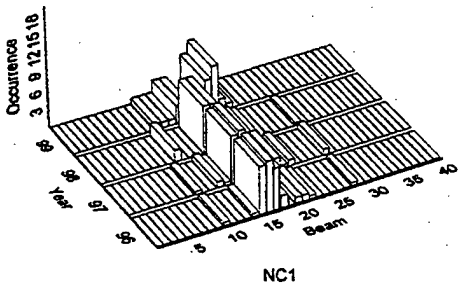


NE2

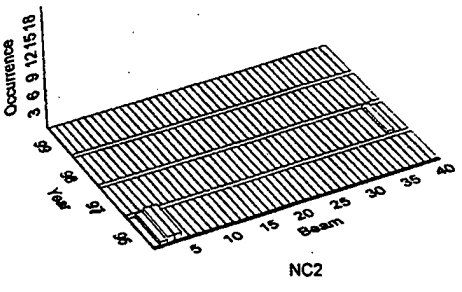


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for June

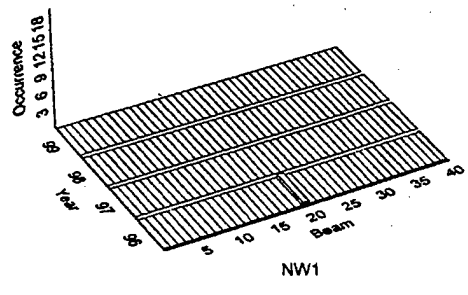


NC1

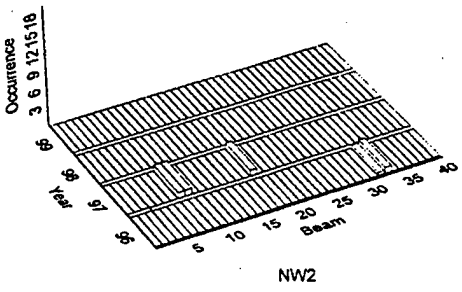


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for June

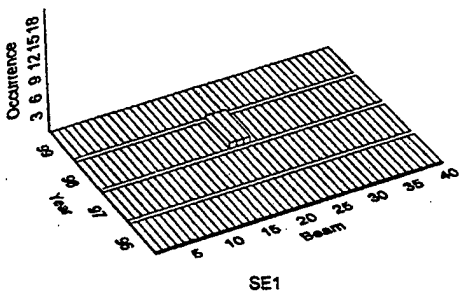


NW1

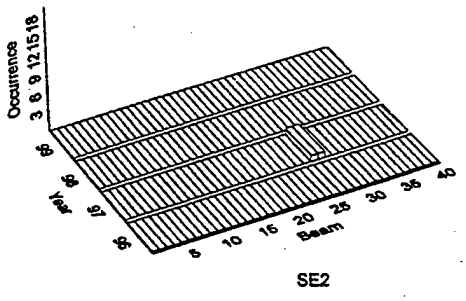


NW2

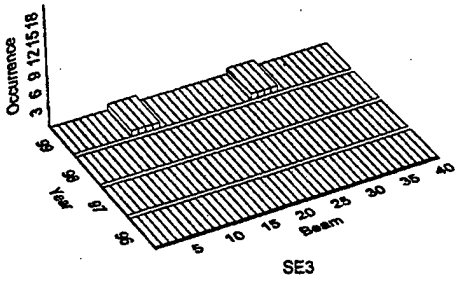
Occurrence of 'F' and 'J' type fin whale calls in SE for June
**No data taken in 1998



SE1

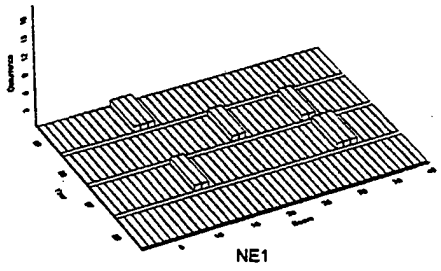


SE2

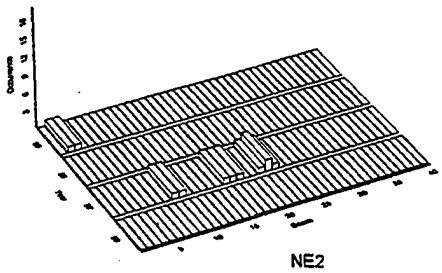


SE3

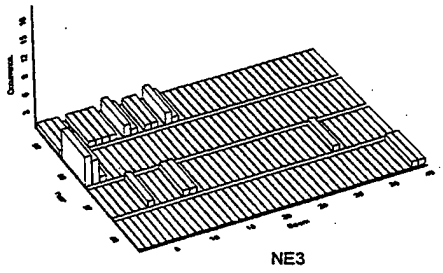
Occurrence of 'F' and 'J' type fin whale calls in NE for July



NE1

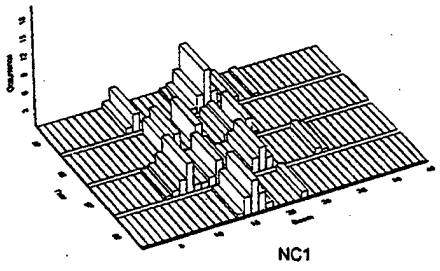


NE2

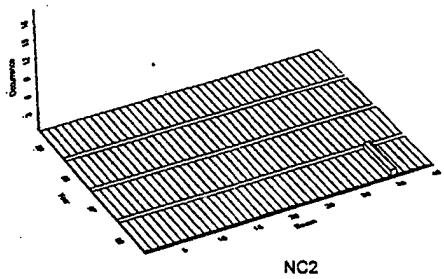


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for July

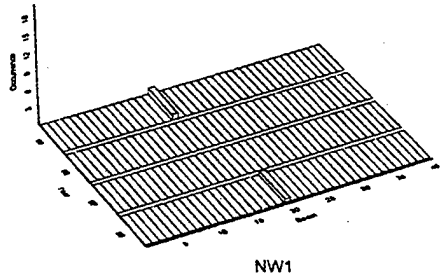


NC1

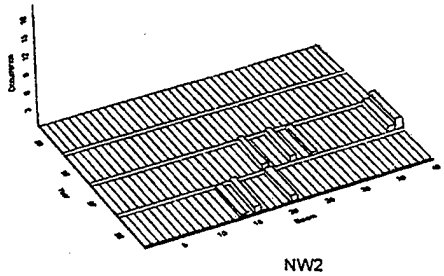


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for July

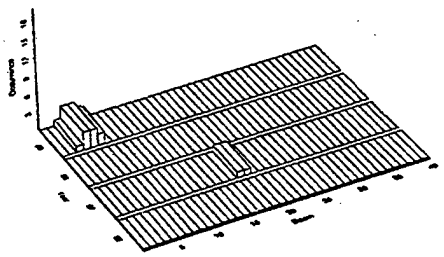


NW1

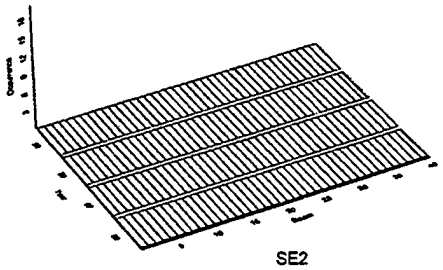


NW2

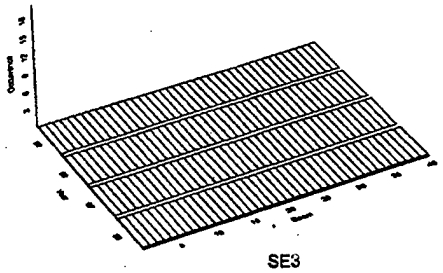
Occurrence of 'F' and 'J' type fin whale calls in SE for July



SE1

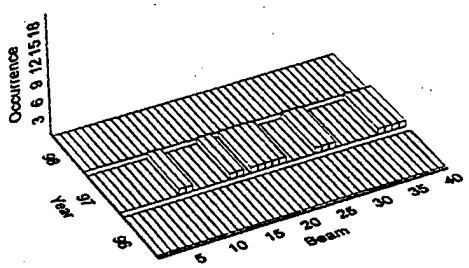


SE2

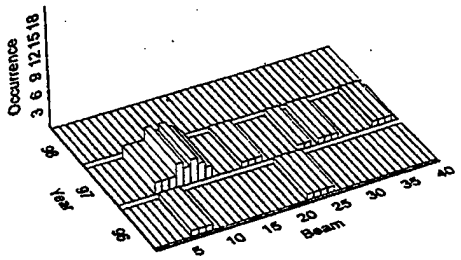


SE3

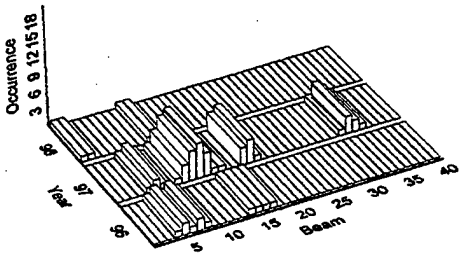
Occurrence of 'F' and 'J' type fin whale calls in NE for August



NE1

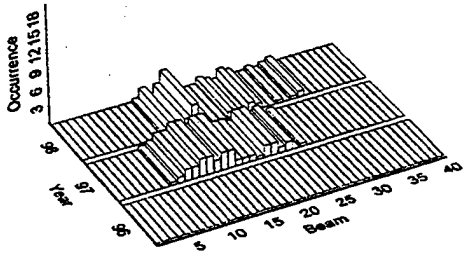


NE2

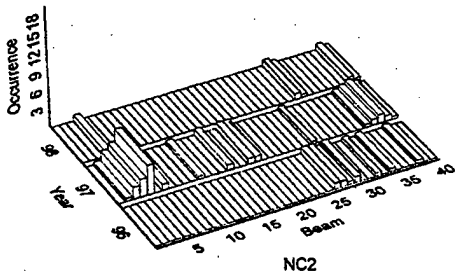


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for August

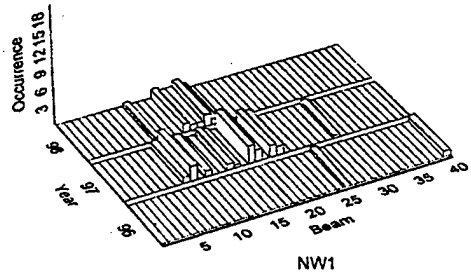


NC1

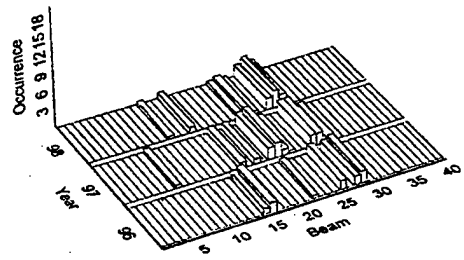


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for August

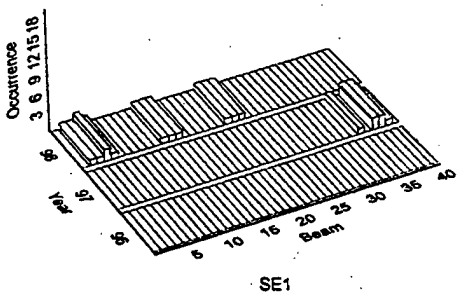


NW1

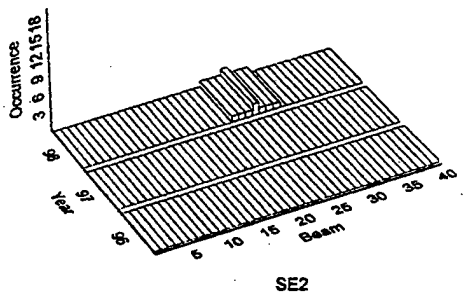


NW2

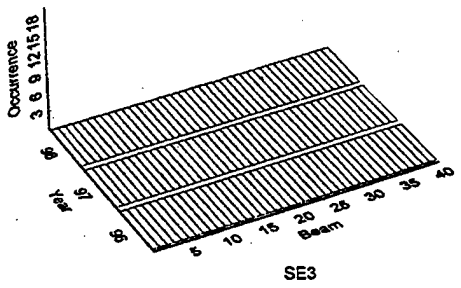
Occurrence of 'F' and 'J' type fin whale calls in SE for August



SE1

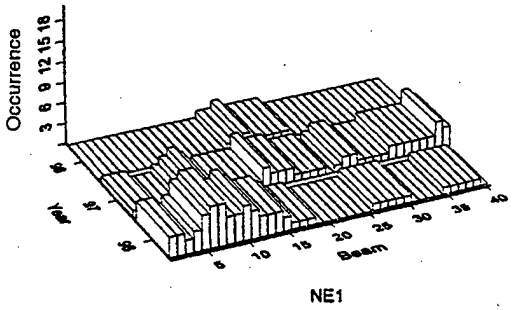


SE2

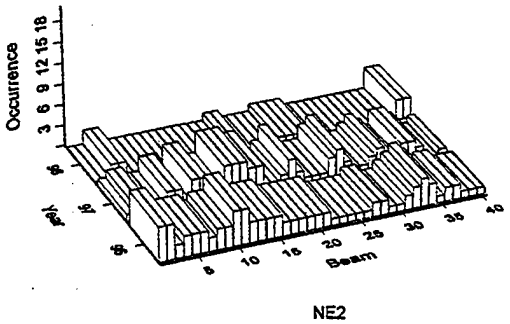


SE3

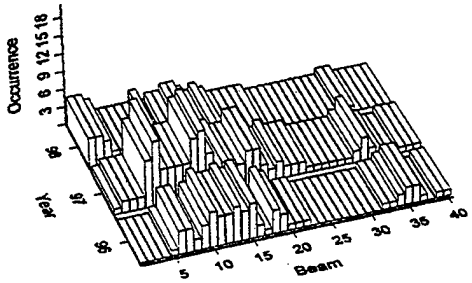
Occurrence of fin whale F type and J type calls in NE for September



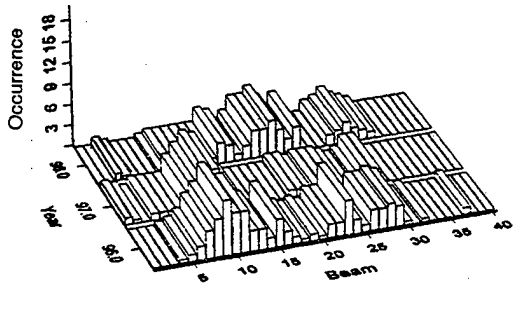
NE1



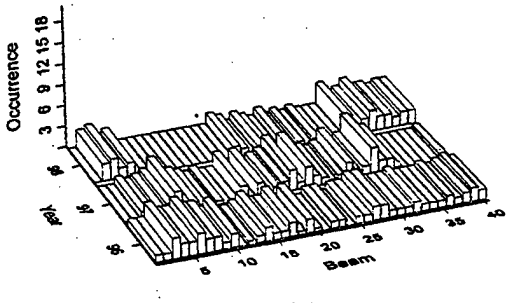
NE2



Occurrence of fin whales 'F' type and 'J' type calls in NC for September

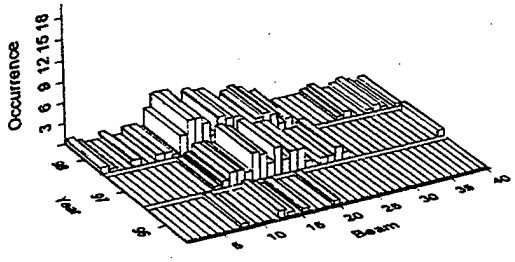


NC1

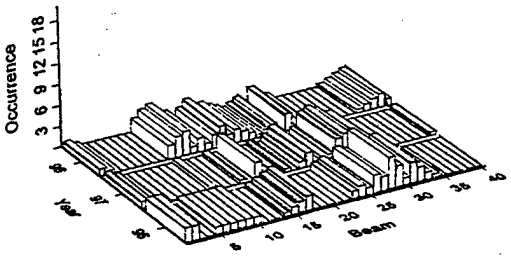


NE2

Occurrence of fin whales 'F' type and 'J' type calls in NW for September

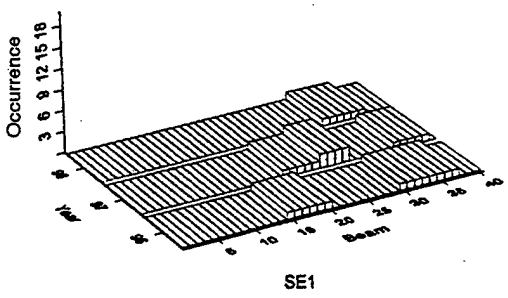


NW1

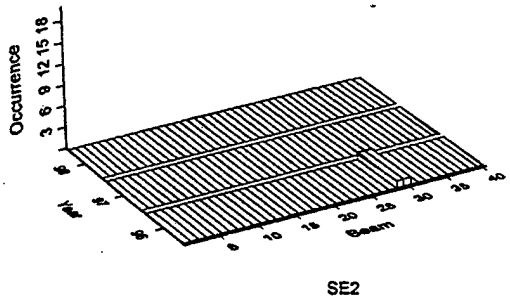


NW2

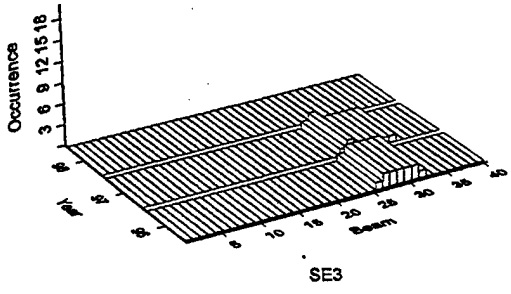
Occurrence of fin whales 'F' type and 'J' type calls in SE for September



SE1

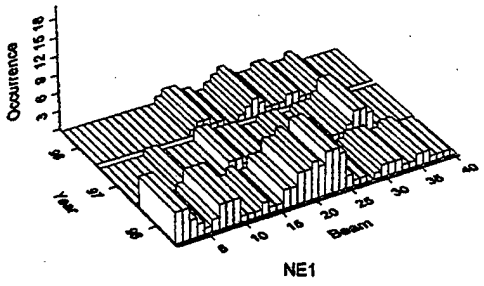


SE2

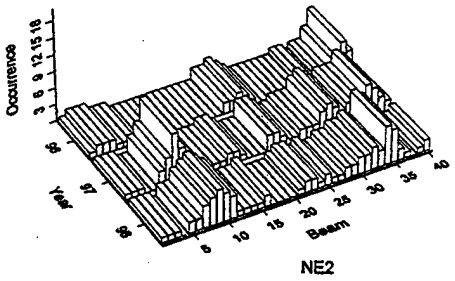


SE3

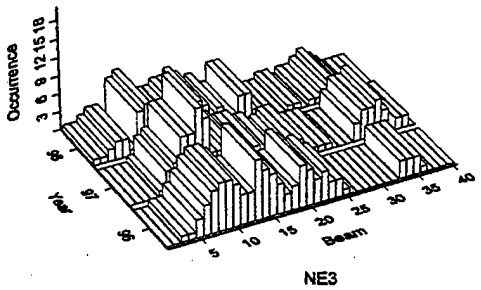
Occurrence of 'F' and 'J' type fin whale calls in NE for October



NE1

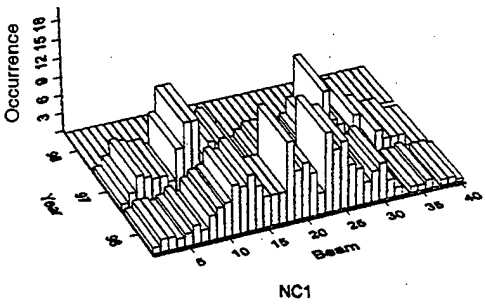


NE2

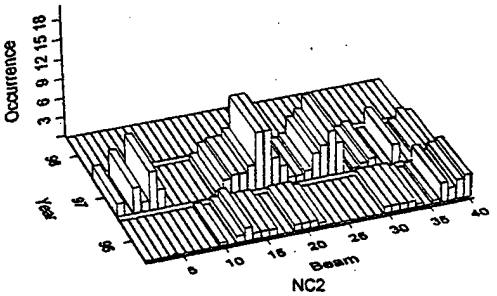


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for October

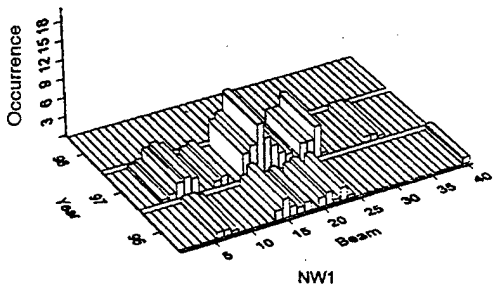


NC1

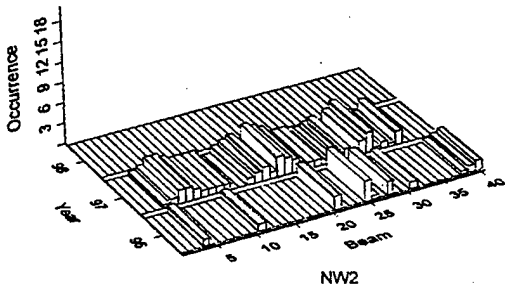


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for October

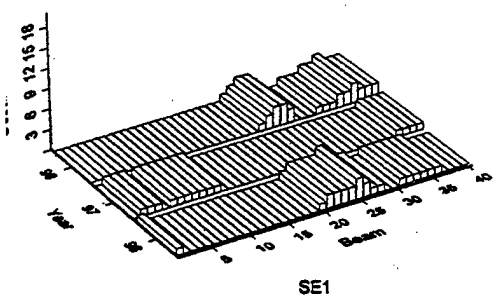


NW1

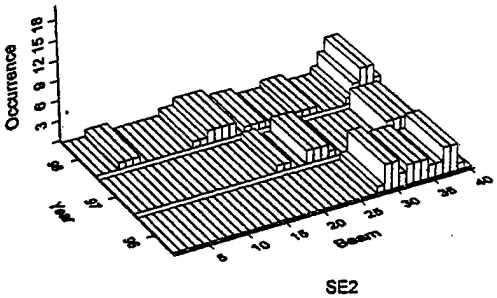


NW2

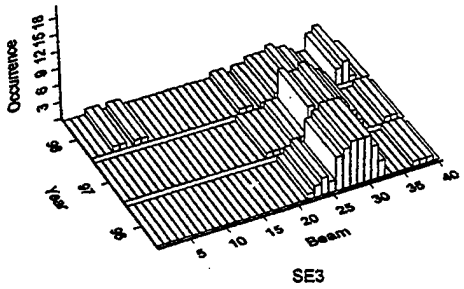
Occurrence of 'F' and 'J' type fin whale calls in SE for October



SE1

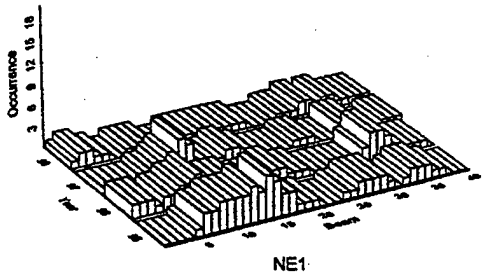


SE2

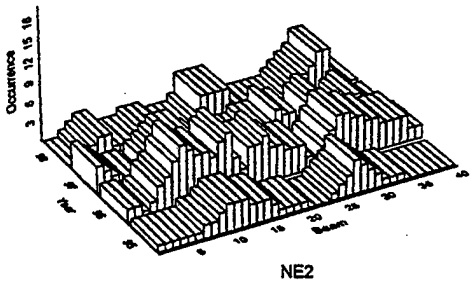


SE3

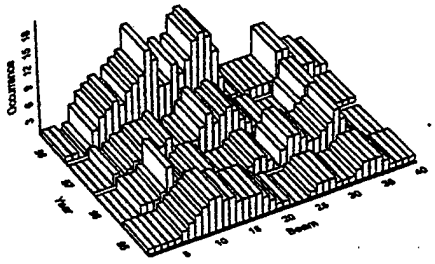
Occurrence of 'F' and 'J' type fin whale calls in NE for November



NE1

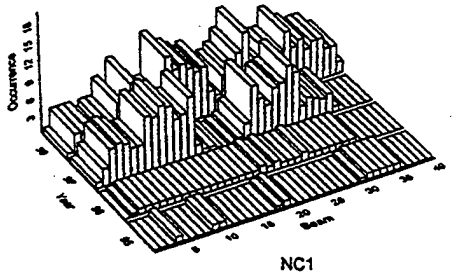


NE2

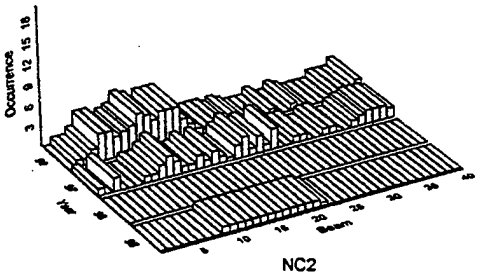


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for November

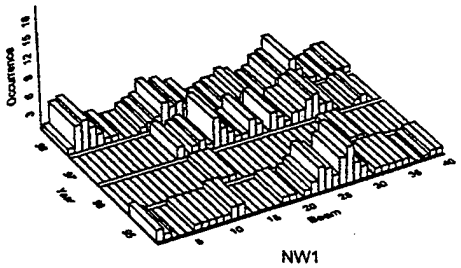


NC1

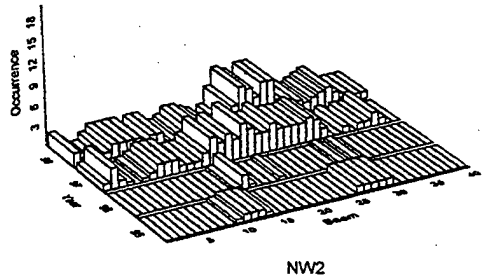


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for November

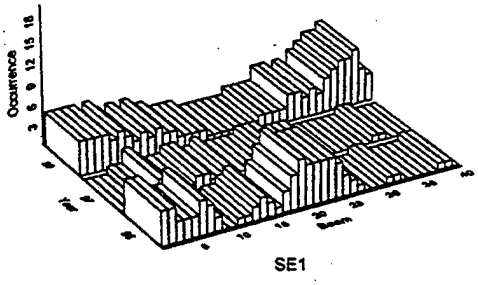


NW1

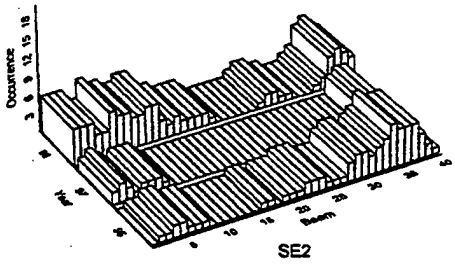


NW2

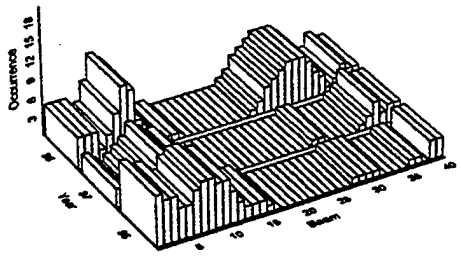
Occurrence of 'F' and 'J' type fin whale calls in SE for November



SE1

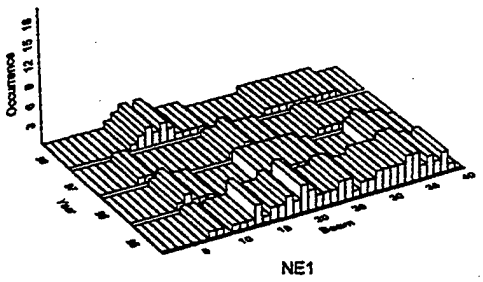


SE2

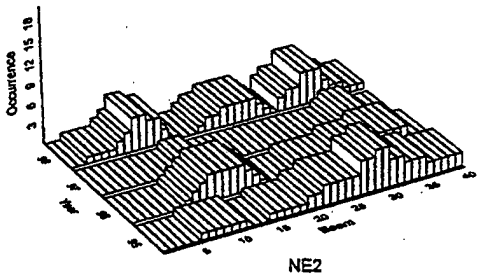


SE3

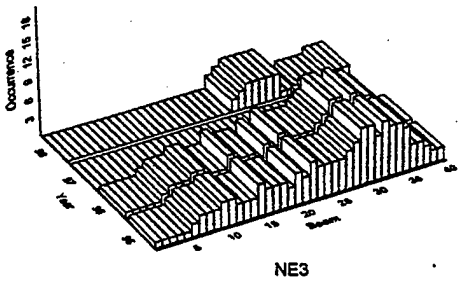
Occurrence of 'F' and 'J' type fin whale calls in NE for December



NE1

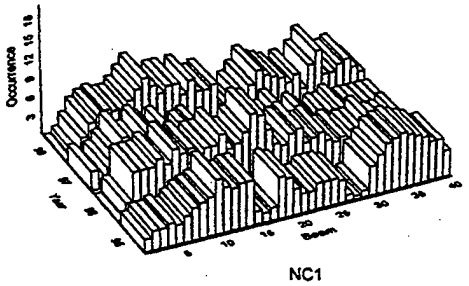


NE2

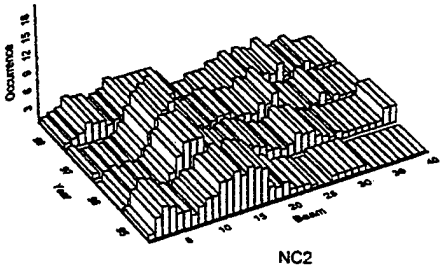


NE3

Occurrence of 'F' and 'J' type fin whale calls in NC for December

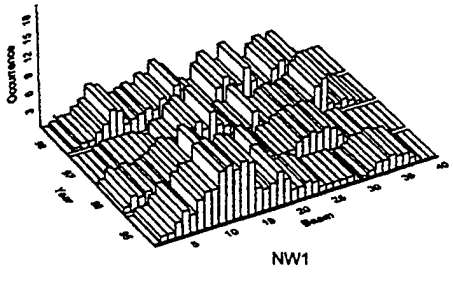


NC1

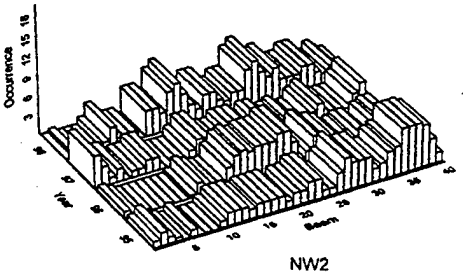


NC2

Occurrence of 'F' and 'J' type fin whale calls in NW for December

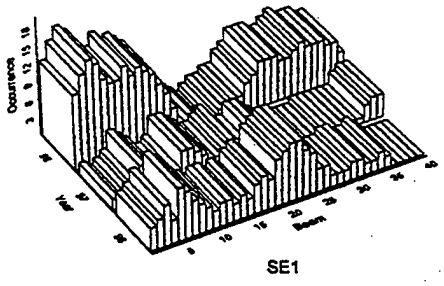


NW1

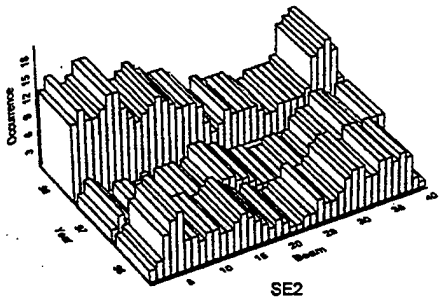


NW2

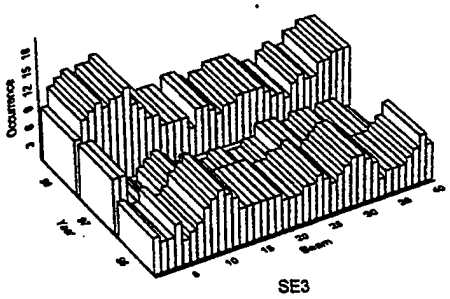
Occurrence of 'F' and 'J' type fin whale calls in SE for December



SE1

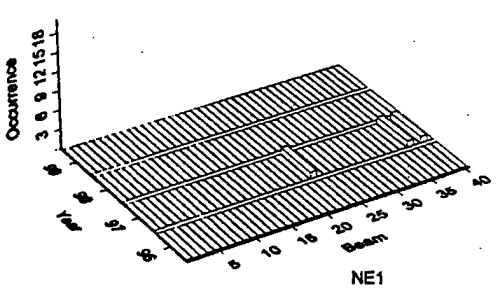


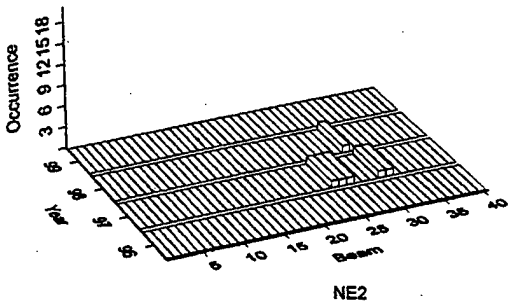
SE2

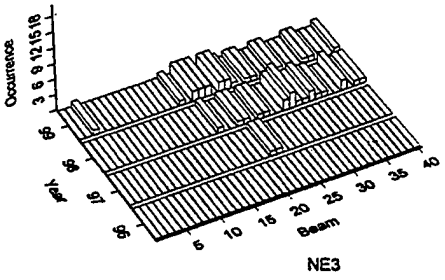


SE3

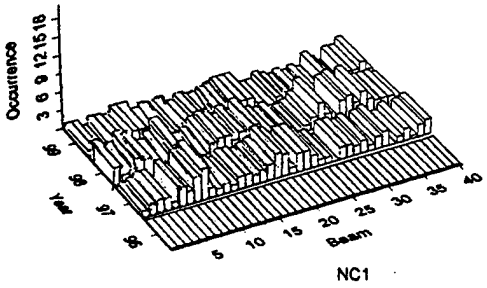
Occurrence of humpback whale calls in NE for January

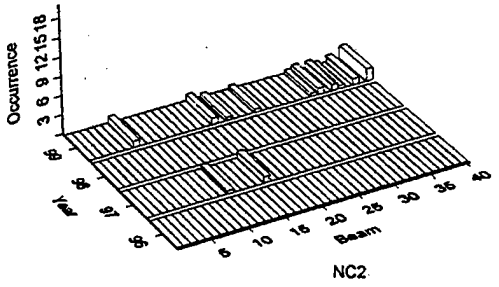




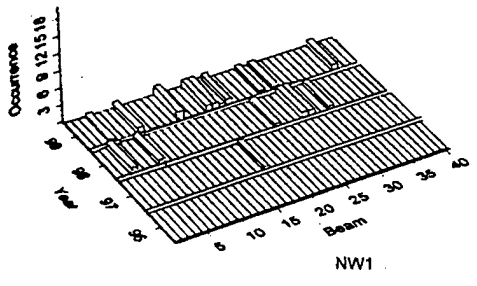


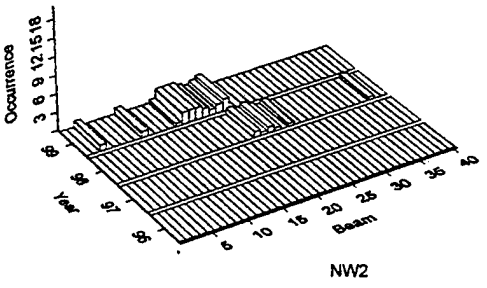
Occurrence of humpback whale calls in NC for January



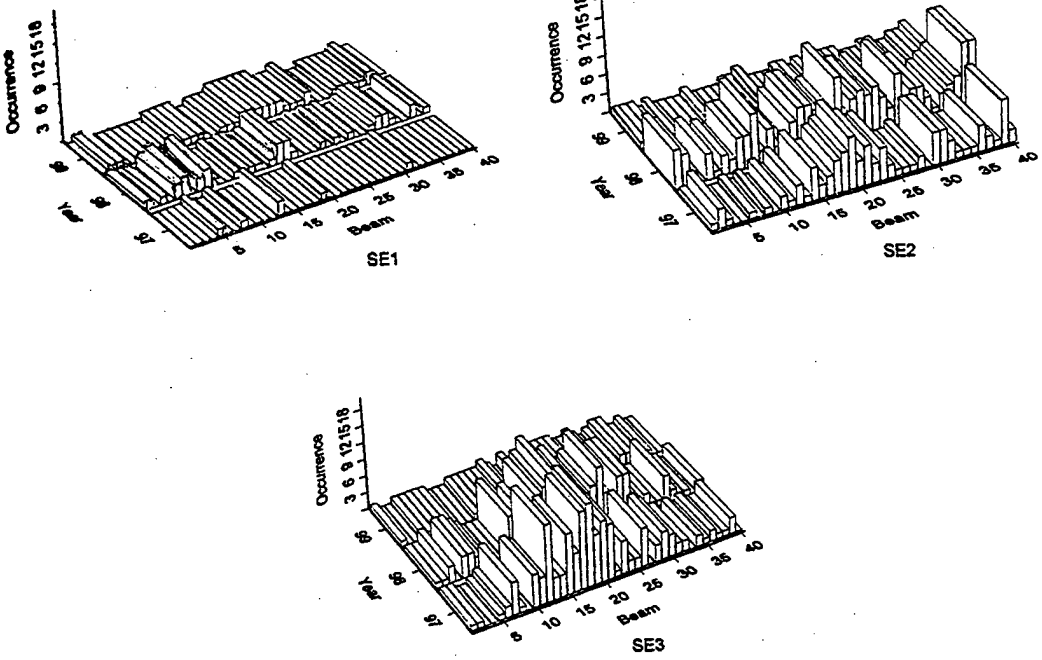


Occurrence of humpback whale calls in NW for January

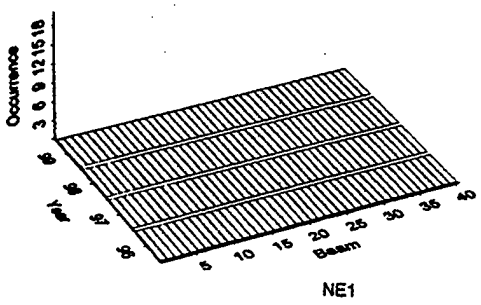




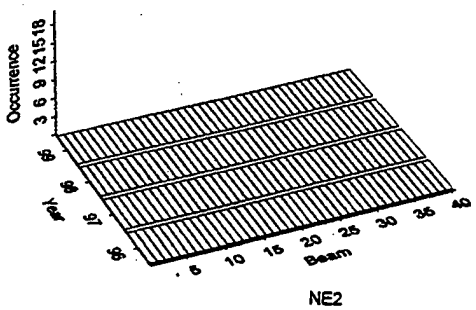
Occurrence of humpback whale calls in SE for January



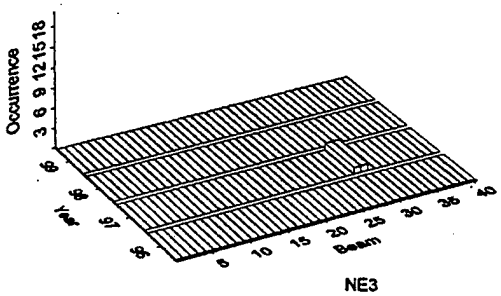
Occurrence of humpback whale calls in NE for February



NE1

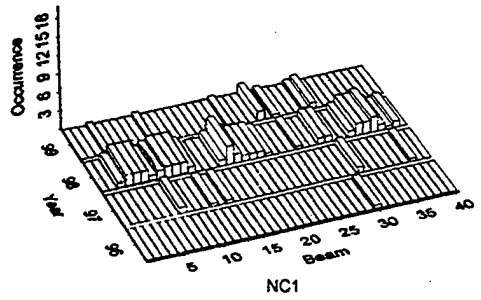


NE2

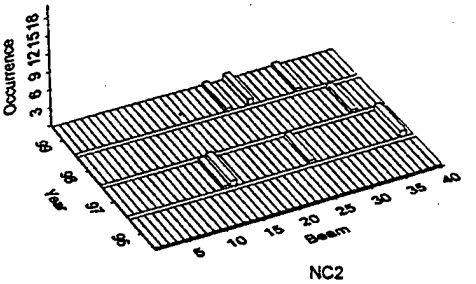


NE3

Occurrence of humpback whale calls in NC for February

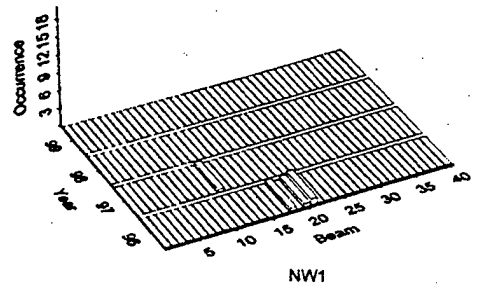


NC1

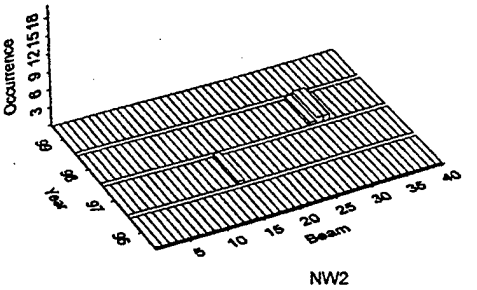


NC2

Occurrence of humpback whale calls in NW for February

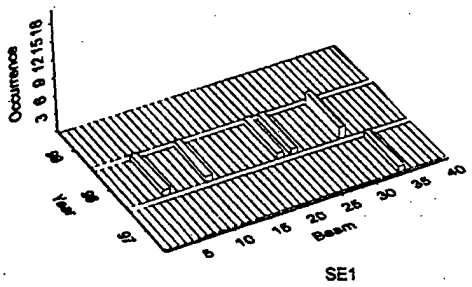


NW1

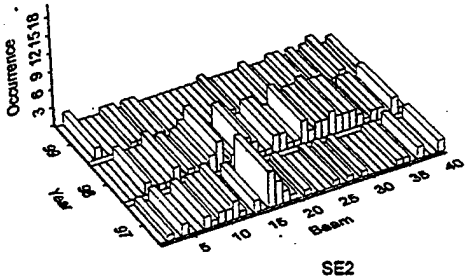


NW2

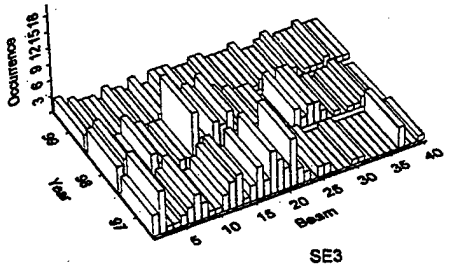
Occurrence of humpback whale calls in SE for February



SE1

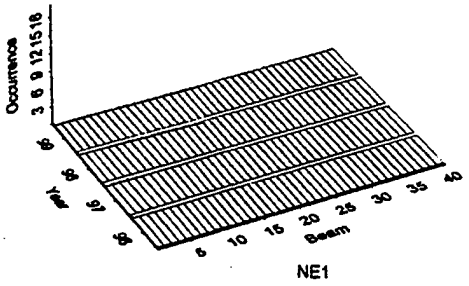


SE2

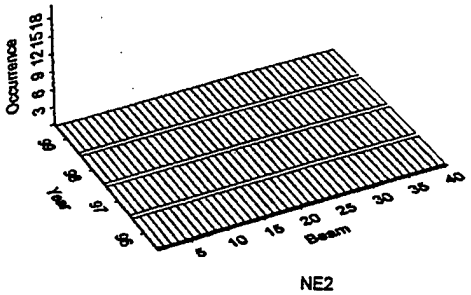


SE3

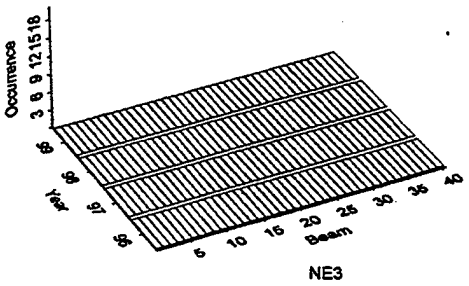
Occurrence of humpback whale calls in NE for March



NE1

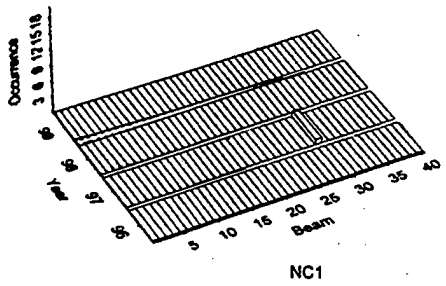


NE2

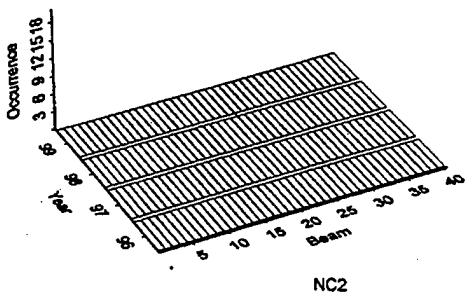


NE3

Occurrence of humpback whale calls in NC for March

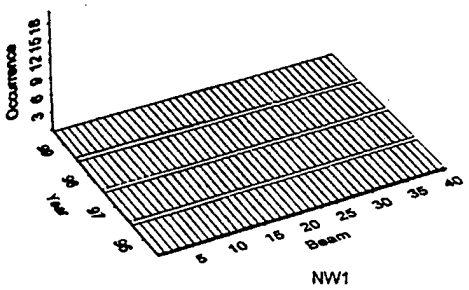


NC1

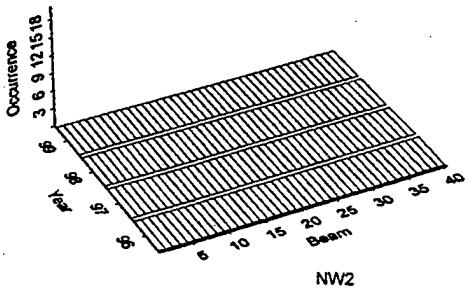


NC2

Occurrence of humpback whale calls in NW for March

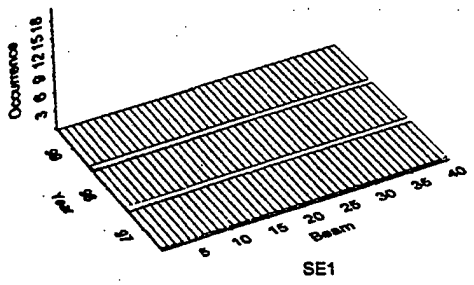


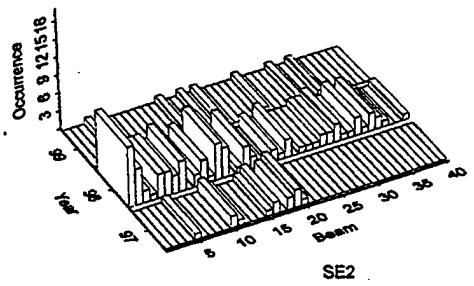
NW1

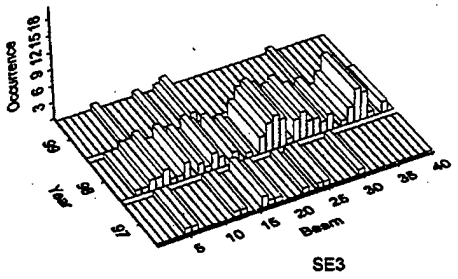


NW2

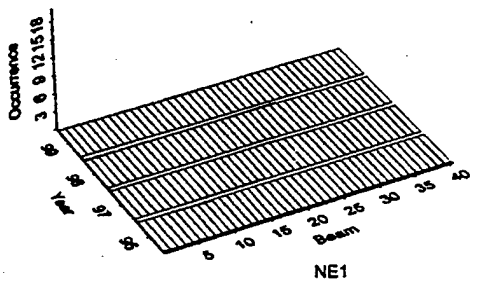
Occurrence of humpback whale calls in SE for March



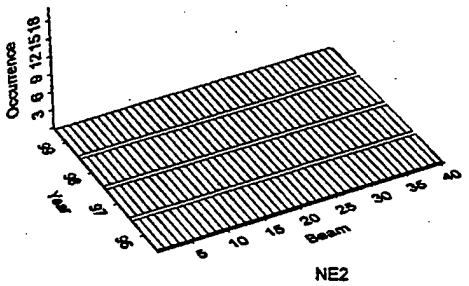




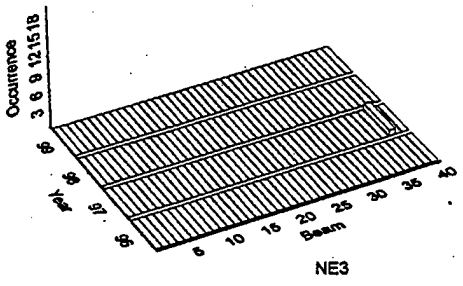
Occurrence of humpback whale calls in NE for April



NE1

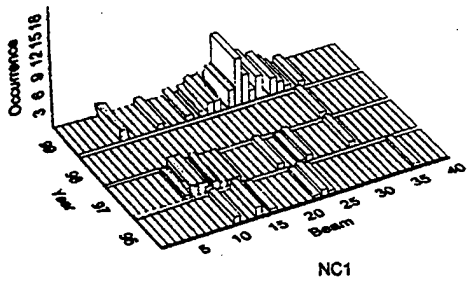


NE2

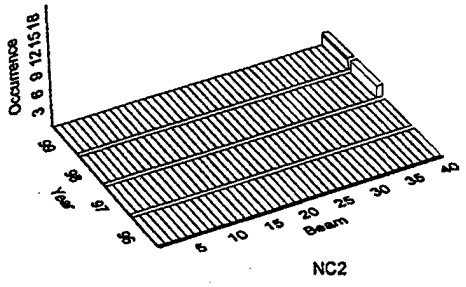


NE3

Occurrence of humpback whale calls in NC for April

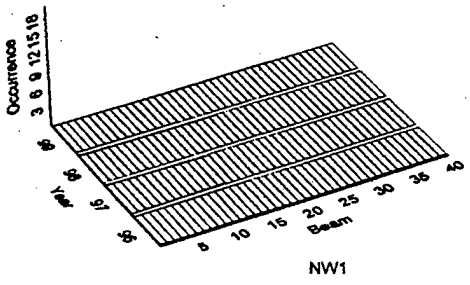


NC1

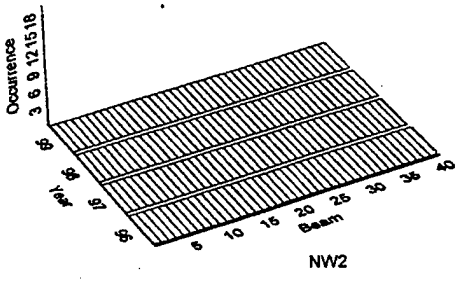


NC2

Occurrence of humpback whale calls in NW for April

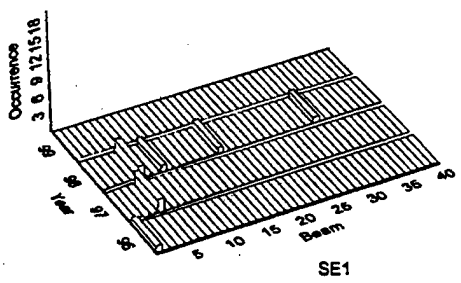


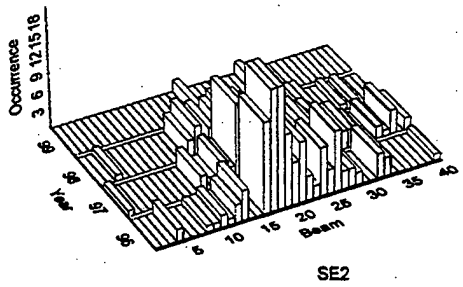
NW1

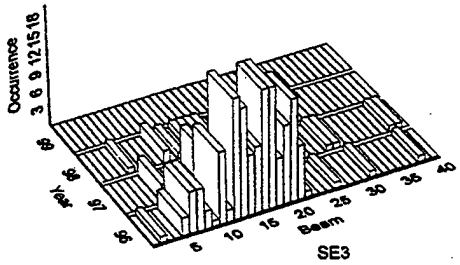


NW2

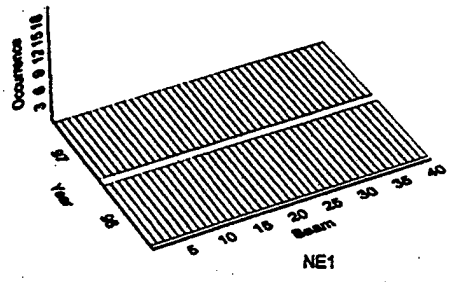
Occurrence of humpback whale calls in SE for April

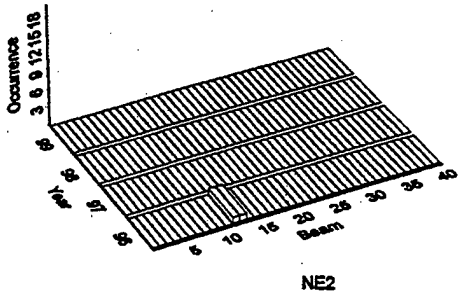


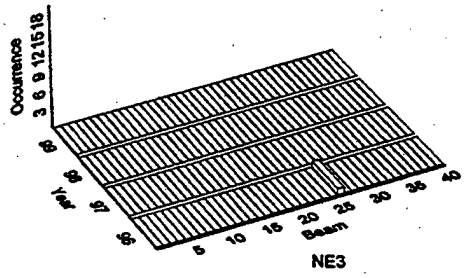




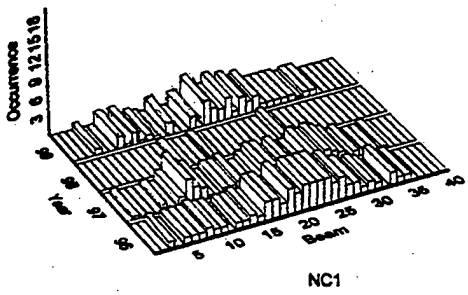
Occurrence of humpback whale calls in NE for May

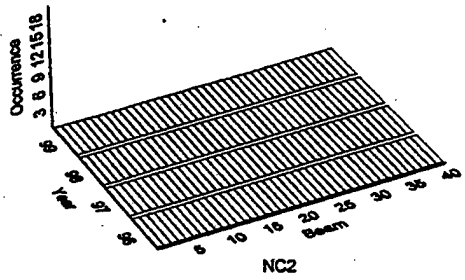




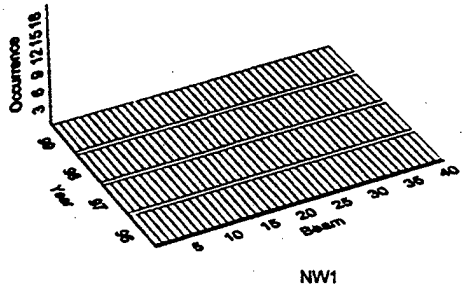


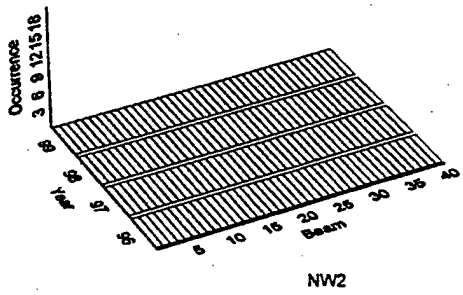
Occurrence of humpback whale calls in NC for May



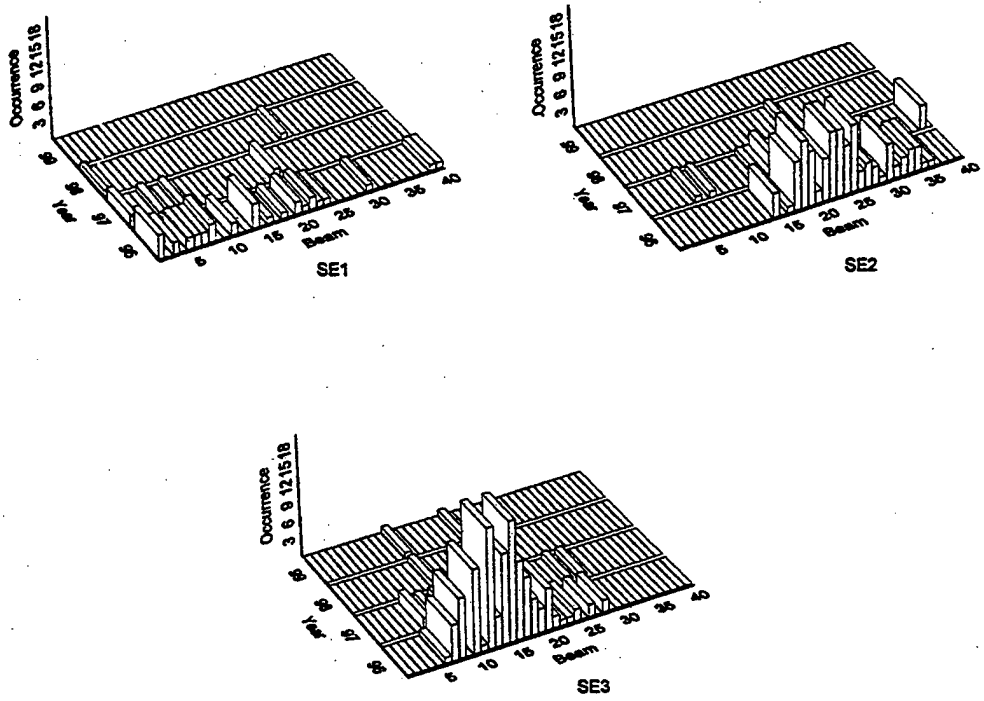


Occurrence of humpback whale calls in NW for May

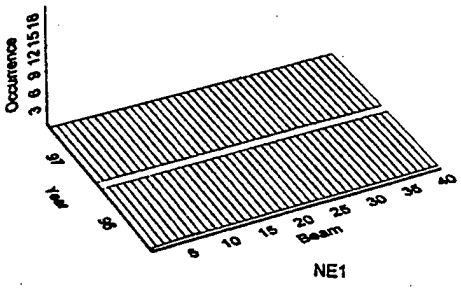


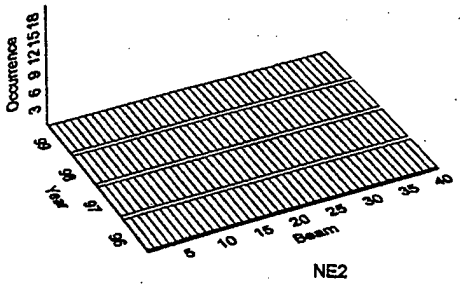


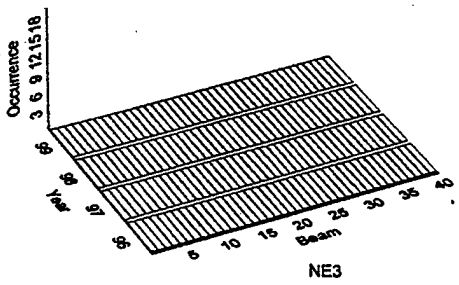
Occurrence of humpback whale calls in SE for May



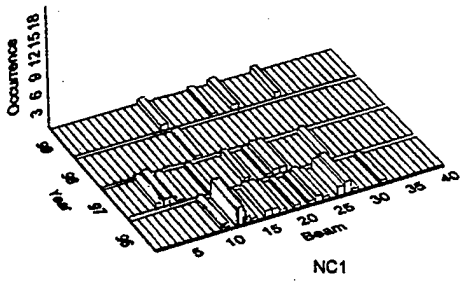
Occurrence of humpback whale calls in NE for June

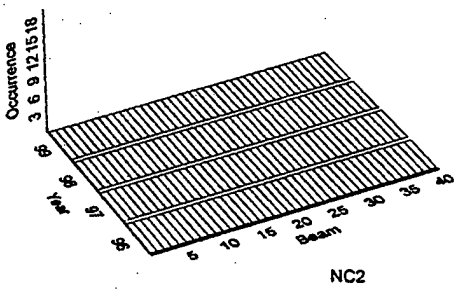




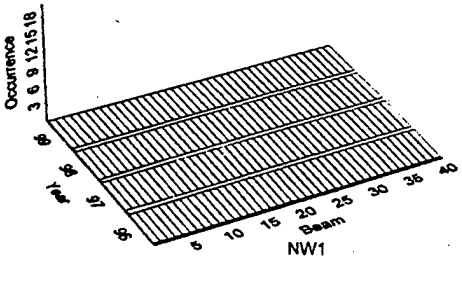


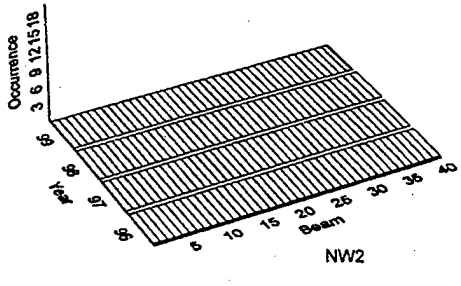
Occurrence of humpback whale calls in NC for June



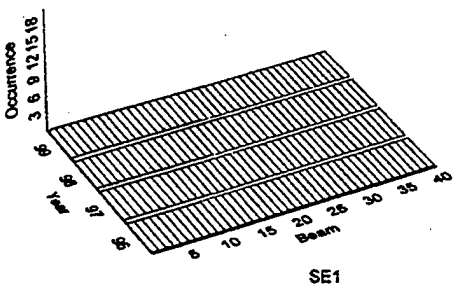


Occurrence of humpback whale calls in NW for June

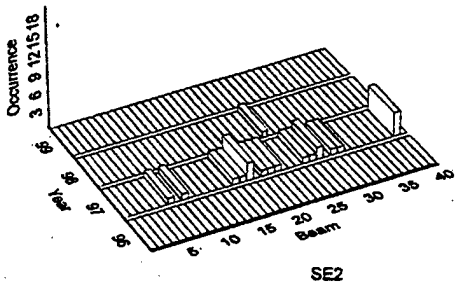




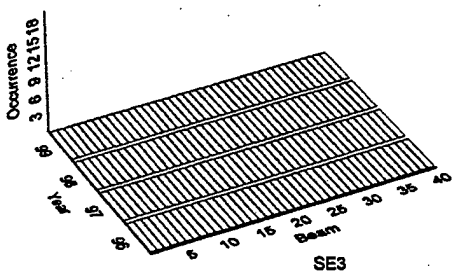
Occurrence of humpback whale calls in SE for June



SE1

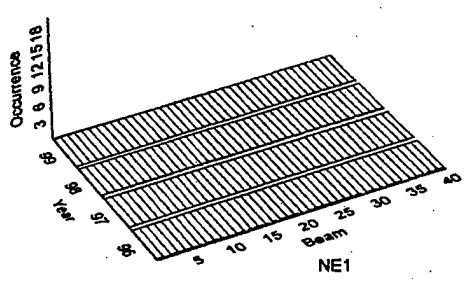


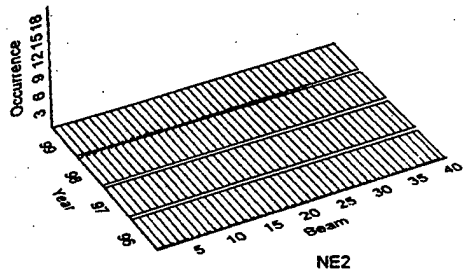
SE2

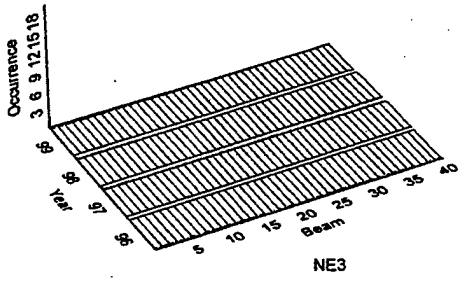


SE3

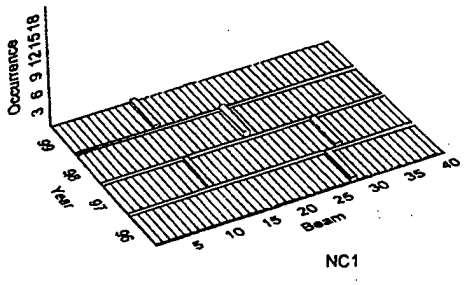
Occurrence of humpback whale calls in NE for July

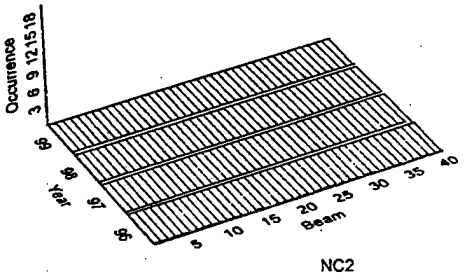




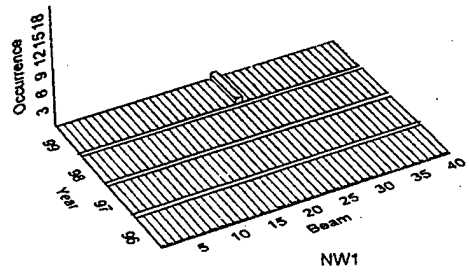


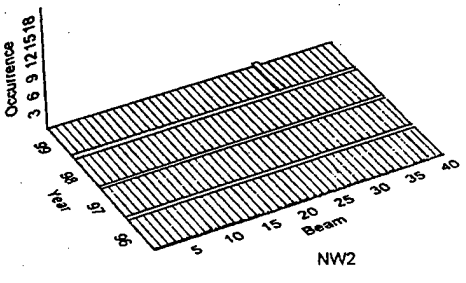
Occurrence of humpback whale calls in NC for July



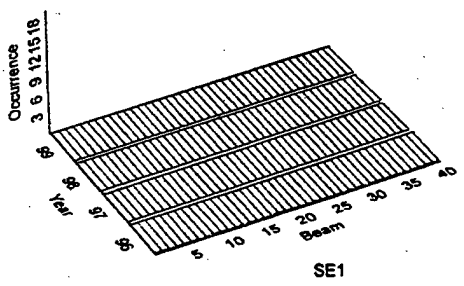


Occurrence of humpback whale calls in NW for July

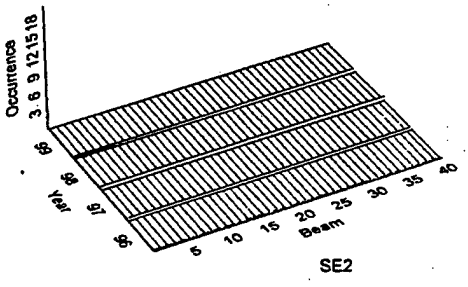




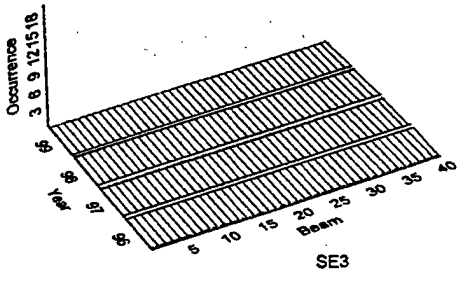
Occurrence of humpback whale calls in SE for July



SE1

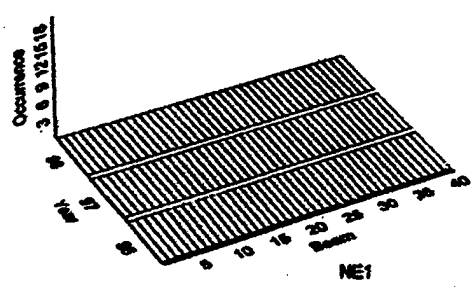


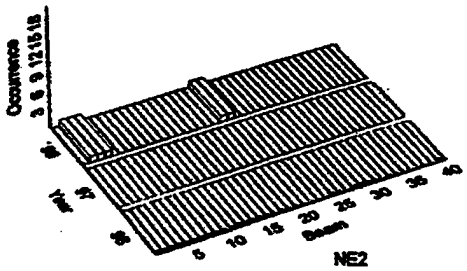
SE2

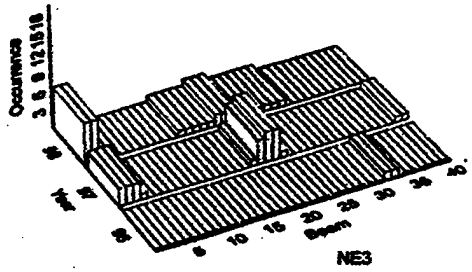


SE3

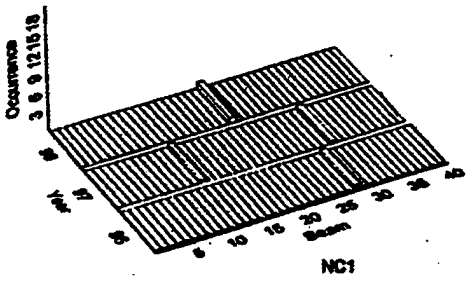
Occurrence of humpback whale calls in NE for November

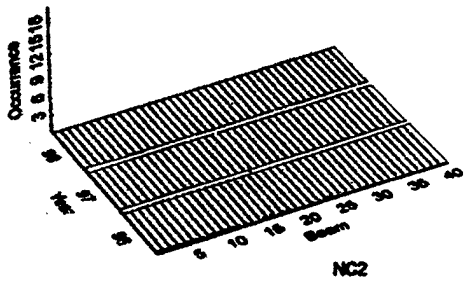




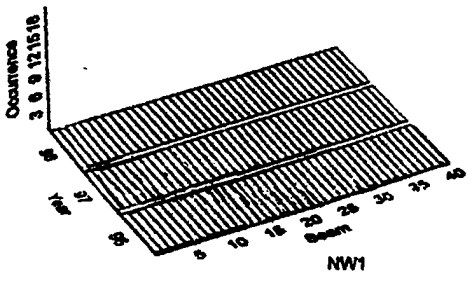


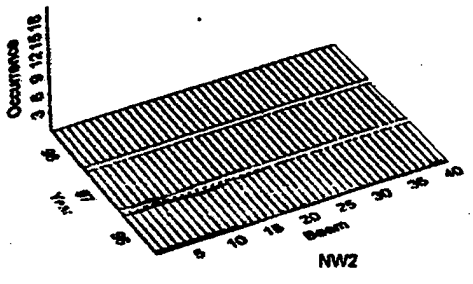
Occurrence of humpback whale calls in NC for November



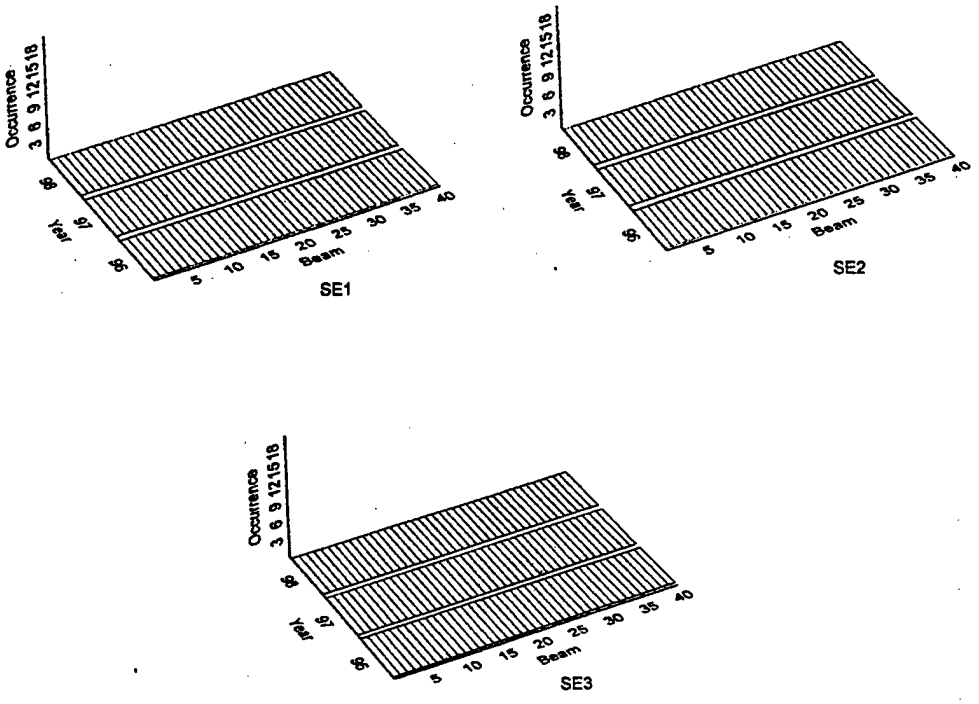


Occurrence of humpback whale calls in NW for November

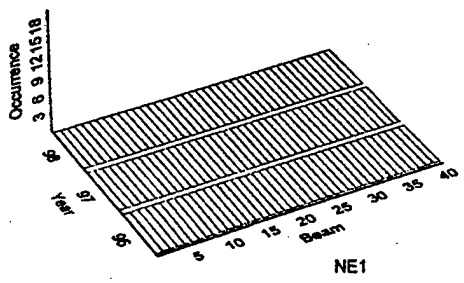




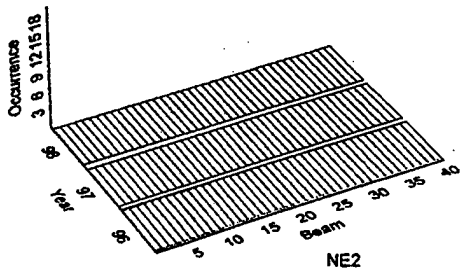
Occurrence of humpback whale calls in SE for November



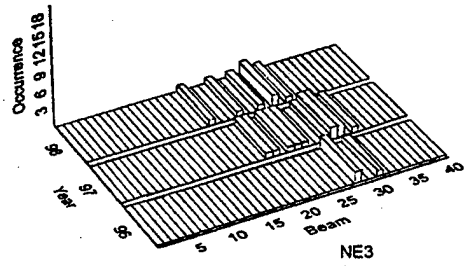
Occurrence of humpback whale calls in NE for December



NE1

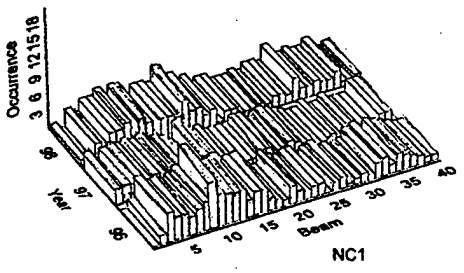


NE2

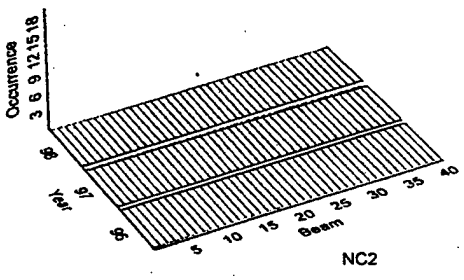


NE3

Occurrence of humpback whale calls in NC for December

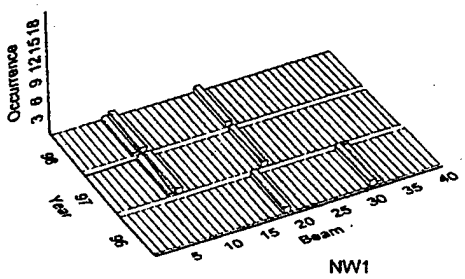


NC1

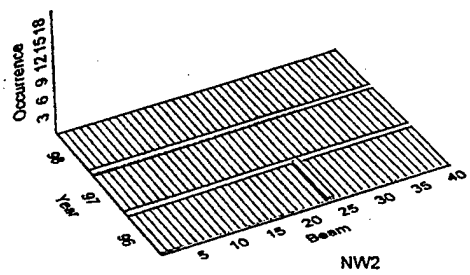


NC2

Occurrence of humpback whale calls in NW for December

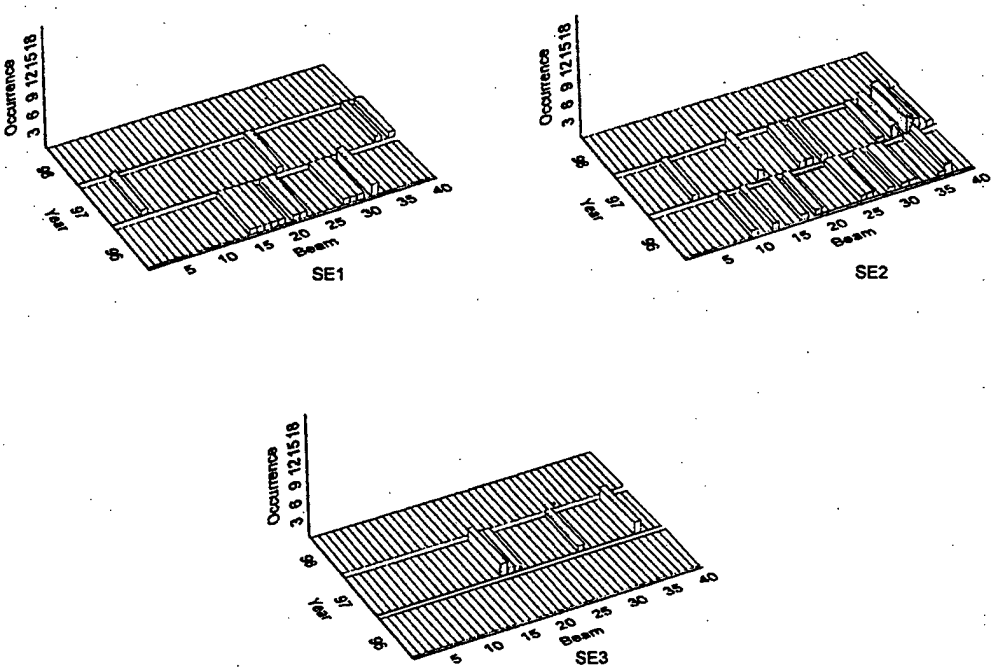


NW1



NW2

Occurrence of humpback whale calls in SE for December



Numbers of Blue Whales Calling

	Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun
1995	**ACTUAL**	**x1.5**	**ACTUAL**	**x1.5**	**ACTUAL**	**x1**	**ACTUAL**	**x1**	**ACTUAL**	**x1**	**ACTUAL**	**x1.5**
NE1												
NE2												
NE3												
NC1												
NC2												
NW1												
NW2												
SE1												
SE2												
SE3												
1996												
NE1	12	18	0	0	13	13	0	0	0	0	0	0
NE2	2	3	0	0	0	0	0	0	0	0	8	12
NE3	4	6	16	24	0	0	0	0	0	0	13	20
NC1	20	29	11	17	12	12	6	6	0	0	2	3
NC2	32	47	42	62	15	15	1	1	7	7	18	26
NW1	32	47	13	19	5	5	4	4	5	5	37	56
NW2	73	109	51	76	6	6	5	5	19	19	55	83
SE1							0	0	0	0	0	0
SE2							0	0	0	0	0	0
SE3							0	0	0	0	0	0
1997												
NE1	2	3	0	0	0	0	6	6	0	0	0	0
NE2	16	24	7	11	0	0	0	0	0	0	5	8
NE3	34	51	7	11	0	0	3	3	0	0	6	9
NC1	33	49	12	18	7	7	5	5	1	1	4	6
NC2	54	81	33	50	20	20	8	8	4	4	11	17
NW1	36	54	15	22	22	22	13	13	25	25	42	63
NW2	39	58	10	15	21	21	14	14	33	33	73	110
SE1	32	48	13	20	24	24	18	18	18	18	0	0
SE2	36	54	23	35	34	34	6	6	2	2	0	0
SE3	20	30	45	68	36	36	8	8	1	1	3	5
1998												
NE1	5	8	0	0	0	0	0	0	0	0	0	0
NE2	3	5	0	0	0	0	0	0	0	0	0	0
NE3	15	23	18	90	5	5	0	0	0	0	2	3
NC1	36	54	20	29	12	12	0	0	1	1	8	12
NC2	99	168	43	64	29	29	6	6	13	13	24	35
NW1	60	90	27	41	20	20	8	8	31	31	55	82
NW2	32	48	5	8	4	4	9	9	42	42	98	147
SE1	29	44	3	5	26	26	22	22	0	0	21	32
SE2	26	39	28	42	16	16	3	3	0	0	1	2
SE3	52	78	23	35	7	7	0	0	2	2	3	5
1999												
NE1	3	5	0	0	0	0	0	0	0	0	0	0
NE2	19	29	12	18	0	0	0	0	0	0	0	0
NE3	22	33	15	23	7	7	0	0	0	0	0	0
NC1	40	60	22	32	12	12	0	0	0	0	16	24
NC2	51	76	45	68	11	11	7	7	9	9	27	41
NW1	53	80	20	29	11	11	22	22	22	22	34	50
NW2	61	92	11	16	6	6	28	28	23	23	53	79
SE1	60	90	28	42	10	10	0	0	1	1	17	26
SE2	102	153	78	117	37	37	0	0	0	0	0	0
SE3	65	98	41	62	63	63	0	0	1	1	8	12

Whale Call Data – Page 142

Numbers of Blue Whales Calling

	Jul	Jul	Aug	Aug	Sept	Sept	Oct	Oct	Nov	Nov	Dec	Dec
1995	**ACTUAL**	**x1.5**	**ACTUAL**	**x1.5**	**ACTUAL**	**x5**	**ACTUAL**	**x5**	**ACTUAL**	**x5**	**ACTUAL**	**x1.5**
NE1									21	105	17	26
NE2									11	55	16	24
NE3									61	305	14	21
NC1									86	428	47	71
NC2									91	455	85	127
NW1									205	1025	97	145
NW2									107	533	85	127
SE1												
SE2												
SE3												
1996												
NE1	8	12	31	47					37	185	0	0
NE2	1	2	31	47					14	70	41	62
NE3	21	32	51	77					60	300	29	44
NC1	19	29	53	79					13	63	56	84
NC2	53	80	140	210					1	5	82	123
NW1	123	184	265	397					25	125	104	156
NW2	125	187	165	247					29	145	108	162
SE1	9	14	28	42					70	350	103	155
SE2	4	6	28	42					44	220	105	158
SE3	17	26	48	72					59	295	69	104
1997												
NE1	2	3	17	26					21	105	5	8
NE2	8	12	31	47					28	140	4	6
NE3	16	24	63	95					96	480	31	47
NC1	38	57	98	147					107	533	65	98
NC2	47	70	174	261					279	1395	129	194
NW1	94	140	273	410					213	1065	125	188
NW2	121	181	187	281					226	1128	190	284
SE1	31	47	67	101					69	345	68	102
SE2	9	14	80	120					62	310	61	92
SE3	28	42	83	125					88	440	46	69
1998												
NE1	0	0	21	32					38	190	49	74
NE2	3	5	22	33					32	160	18	27
NE3	14	21	54	81					77	385	62	93
NC1	44	66	104	156					110	548	104	155
NC2	56	84	311	467					139	695	159	238
NW1	120	180	385	577					300	1498	115	173
NW2	158	237	312	468					176	880	144	216
SE1	28	42	86	129					90	450	115	173
SE2	1	2	45	68					85	425	95	143
SE3	23	35	61	92					105	525	91	137
1999												
NE1	8	12										
NE2	0	0										
NE3	10	15										
NC1	59	89										
NC2	87	131										
NW1	122	183										
NW2	141	212										
SE1	12	18										
SE2	12	18										
SE3	46	69										

Whale Call Data - Page 143

Numbers of Fin whales, F Calls

	January	January	February	February	March	March	April	April	May	May	Jun	Jun
1995	Actual	X3	Actual	x3	Actual	x1.5	Actual	x1.5	Actual	x1.5	Actual	x1
NE1												
NE2												
NE3												
NC1												
NC2												
NW1												
NW2												
SE1												
SE2												
SE3												
1996												
NE1	96	288	31	93	24	36	42	63	12	18	0	0
NE2	58	174	40	120	117	176	65	98	7	11	0	0
NE3	9	27	3	9	55	83	40	60	5	8	0	0
NC1	20	60	8	24	24	36	4	6	0	0	1	1
NC2	2	6	16	48	25	38	2	3	3	5	0	0
NW1	11	33	25	75	22	33	8	12	6	9	1	1
NW2	10	30	13	39	23	35	6	9	22	33	2	2
SE1									0	0	0	0
SE2									0	0	0	0
SE3									0	0	0	0
1997												
NE1	113	339	60	180	35	53	11	17	11	17	8	8
NE2	102	306	110	330	129	194	77	116	43	65	2	2
NE3	85	255	67	201	51	77	41	62	13	20	0	0
NC1	36	108	26	78	17	26	4	6	6	9	7	7
NC2	27	81	21	63	22	33	25	38	0	0	0	0
NW1	22	66	30	90	13	20	17	26	0	0	0	0
NW2	55	165	42	126	19	29	32	48	2	3	0	0
SE1	74	222	77	231	191	287	106	159	9	14	0	0
SE2	113	339	164	492	69	104	33	50	0	0	2	2
SE3	145	435	191	573	113	170	72	108	11	17	0	0
1998												
NE1	19	57	33	99	64	96	20	30				
NE2	28	84	19	57	56	84	19	29	2	3	0	0
NE3	34	102	3	9	14	21	14	21	0	0	0	0
NC1	53	50	29	87	33	50	2	3	8	12	1	1
NC2	30	90	5	15	21	32	23	35	3	5	0	0
NW1	65	195	24	72	14	21	25	38	4	6	0	0
NW2	85	255	38	114	19	29	14	21	22	33	0	0
SE1	83	249	89	267	106	159	63	95	20	30		
SE2	87	261	132	396	93	140	22	33	0	0	0	0
SE3	130	390	159	477	150	225	45	68	3	5	0	0
1999												
NE1	105	315	86	258	84	126	42	63	2	3		
NE2	52	156	83	249	49	74	52	78	7	11	2	2
NE3	85	255	49	147	109	164	58	87	4	6	0	0
NC1	125	375	106	318	89	134	40	60	4	6	2	2
NC2	48	144	15	45	30	45	24	36	0	0	0	0
NW1	46	138	37	111	46	69	44	66	7	11	0	0
NW2	86	258	19	57	18	27	17	26	5	8	0	0
SE1	276	828	268	804	275	413	92	138	9	14	0	0
SE2	321	963	146	438	126	189	42	63	2	3	4	4
SE3	306	918	407	1221	250	375	234	351	11	17	0	0

Whale Call Data - Page 144

Numbers of Fin Whales, F Calls

	Jul	Jul	Aug	Aug	Sept	Sept	Oct	Oct	Nov	Nov	Dec	Dec
1995	**Actual**	**x1**	**Actual**	**x1**	**Actual**	**x1.5**	**Actual**	**x1.5**	**Actual**	**x1.5**	**Actual**	**x3**
NE1									72	108	62	186
NE2									59	89	33	99
NE3									69	104	26	78
NC1									0	0	3	9
NC2									0	0	0	0
NW1									0	0	4	12
NW2									0	0	12	36
SE1												
SE2												
SE3												
1996												
NE1	0	0	0	0	69	104	104	156	57	86	37	111
NE2	0	0	7	7	84	126	60	90	150	225	43	129
NE3	2	2	11	11	74	111	123	185	69	104	31	93
NC1	4	4	0	0	37	56	65	98	3	5	30	90
NC2	1	1	5	5	48	72	21	32	0	0	34	102
NW1	1	1	2	2	3	5	19	29	1	2	10	30
NW2	3	3	8	8	30	45	13	20	5	8	13	39
SE1	0	0	0	0	1	2	1	2	40	60	77	231
SE2	0	0	0	0	0	0	0	0	15	23	118	354
SE3	0	0	0	0	0	0	4	6	30	45	154	462
1997												
NE1	5	5	16	16	57	86	29	44	36	54	10	30
NE2	9	9	33	33	90	135	62	93	97	146	12	36
NE3	4	4	40	40	132	198	117	176	106	159	65	195
NC1	6	6	11	11	20	30	107	161	63	95	41	123
NC2	0	0	20	20	42	63	74	111	38	57	30	90
NW1	0	0	15	15	36	54	46	69	32	48	44	132
NW2	3	3	13	13	24	36	39	59	58	87	50	150
SE1	8	8	3	3	0	0	10	15	24	36	83	249
SE2	0	0	0	0	0	0	2	3	15	23	49	147
SE3	0	0	0	0	2	3	2	3	25	38	76	228
1998												
NE1	2	2	0	0	9	14	25	38	31	47	27	81
NE2	0	0	0	0	14	21	24	36	30	45	12	36
NE3	0	0	2	2	48	72	97	146	239	359	125	375
NC1	12	12	9	9	47	71	0	0	151	227	92	276
NC2	0	0	4	4	34	51	0	0	16	24	33	99
NW1	0	0	7	7	59	89	0	0	34	51	83	249
NW2	0	0	11	11	38	57	0	0	50	75	65	195
SE1	0	0	11	11	6	9	7	11	97	146	220	660
SE2	0	0	0	0	0	0	9	14	66	99	323	969
SE3	0	0	0	0	0	0	14	21	68	102	312	936
1999												
NE1	3	3										
NE2	2	2										
NE3	12	12										
NC1	7	7										
NC2	0	0										
NW1	1	1										
NW2	0	0										
SE1	9	9										
SE2	0	0										
SE3	0	0										

Whale Call Data – Page 145

Numbers of Fin Whales, J Calls

	Jan	Jan	Feb	Feb	March	March	April	April	May	May	Jun	Jun
1995	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**
NE1												
NE2												
NE3												
NC1												
NC2												
NW1												
NW2												
SE1												
SE2												
SE3												
1996												
NE1	23	138	3	18	0	0	0	0	0	0	0	0
NE2	40	240	77	462	0	0	0	0	0	0	0	0
NE3	72	432	47	282	5	30	2	12	0	0	2	12
NC1	175	1050	138	828	43	258	31	186	31	186	29	174
NC2	49	294	31	186	43	258	4	24	0	0	3	18
NW1	35	210	41	246	11	66	0	0	2	12	0	0
NW2	57	342	35	210	8	48	0	0	0	0	0	0
SE1									0	0	0	0
SE2									0	0	0	0
SE3									0	0	0	0
1997												
NE1	0	0	0	0	4	24	0	0	0	0	0	0
NE2	3	18	0	0	3	18	0	0	9	54	11	66
NE3	6	36	2	12	2	12	28	168	18	108	6	30
NC1	47	282	52	312	34	204	32	192	27	162	24	144
NC2	22	132	16	96	8	48	3	18	1	6	1	6
NW1	26	156	1	6	7	42	2	12	1	6	0	0
NW2	22	132	3	18	6	36	4	24	4	24	3	18
SE1	50	300	4	24	6	24	0	0	0	0	0	0
SE2	25	150	26	156	8	48	0	0	0	0	0	0
SE3	6	36	0	0	10	60	3	18	0	0	0	0
1998												
NE1	4	24	0	0	0	0	0	0	0	0		
NE2	2	12	16	96	3	18	5	30	13	78	0	0
NE3	44	264	9	54	49	294	33	198	20	120	10	60
NC1	67	402	74	444	46	276	26	156	0	0	23	138
NC2	35	210	62	372	47	282	2	12	0	0	0	0
NW1	10	60	8	48	7	42	2	12	0	0	0	0
NW2	21	126	14	84	11	66	1	6	0	0	0	0
SE1	18	108	0	0	4	24	5	30	0	0	3	18
SE2	35	210	3	18	11	66	3	18	0	0		
SE3	19	114	0	0	0	0	0	0	0	0	0	0
1999												
NE1	0	0	0	0	0	0	0	0	0	0		
NE2	14	84	11	66	7	42	0	0	2	12	0	0
NE3	40	240	84	504	35	210	72	432	14	84	5	30
NC1	57	342	54	324	28	168	74	444	25	150	26	156
NC2	43	258	17	102	12	72	30	180	3	18	0	0
NW1	18	108	10	60	15	90	22	132	0	0	0	0
NW2	4	24	9	54	12	72	16	96	0	0	0	0
SE1	20	120	65	390	37	222	140	840	0	0	0	0
SE2	45	270	106	636	75	450	18	108	0	0	0	0
SE3	12	72	35	210	56	336	36	216	0	0	4	24

Whale Call Data - Page 146

Numbers of Fin Whales, J Calls

	Jul	Jul	Aug	Aug	Sept	Sept	Oct	Oct	Nov	Nov	Dec	Dec
1995	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**	**Actual**	**x6**
NE1									0	0	11	66
NE2									4	24	79	474
NE3									22	132	173	1038
NC1									10	60	187	1122
NC2									14	84	93	558
NW1									50	300	115	690
NW2									9	54	90	540
SE1												
SE2												
SE3												
1996												
NE1	0	0	0	0	0	0	0	0	0	0	0	0
NE2	0	0	0	0	10	60	23	138	43	258	64	384
NE3	0	0	0	0	0	0	3	18	31	186	173	1038
NC1	10	60	0	0	39	234	122	732	30	180	214	1284
NC2	0	0	0	0	5	30	6	18	0	0	79	474
NW1	0	0	0	0	0	0	0	0	6	36	75	450
NW2	0	0	0	0	8	48	1	6	0	0	75	450
SE1	0	0	0	0	13	78	22	132	54	324	93	558
SE2	0	0	0	0	2	12	33	198	63	378	61	366
SE3	0	0	0	0	12	72	53	318	66	396	91	546
1997												
NE1	0	0	0	0	0	0	0	0	0	0	3	18
NE2	0	0	0	0	0	0	37	222	6	36	11	66
NE3	0	0	2	12	6	36	14	84	2	12	10	60
NC1	27	162	19	114	21	126	60	360	117	702	79	474
NC2	0	0	0	0	0	0	17	102	10	60	79	474
NW1	0	0	0	0	0	0	13	78	16	96	31	186
NW2	3	18	0	0	0	0	0	0	19	114	11	66
SE1	2	12	3	18	18	108	4	24	11	66	17	102
SE2	0	0	0	0	0	0	21	126	13	78	43	258
SE3	0	0	0	0	7	42	51	306	30	180	10	60
1998												
NE1	2	12	0	0	0	0	3	18	6	36	0	0
NE2	0	0	0	0	2	12	13	78	59	354	85	510
NE3	10	60	0	0	13	78	3	18	8	48	37	222
NC1	10	60	8	48	3	18	0	0	104	624	0	0
NC2	0	0	0	0	0	0	0	0	55	330	121	726
NW1	0	0	0	0	0	0	0	0	29	174	51	306
NW2	0	0	0	0	0	0	0	0	31	186	55	330
SE1	0	0	0	0	0	0	20	120	39	234	101	606
SE2	0	0	8	48	0	0	27	162	48	288	47	282
SE3	0	0	0	0	0	0	16	96	59	354	42	252
1999												
NE1	0	0										
NE2	0	0										
NE3	3	18										
NC1	16	96										
NC2	0	0										
NW1	0	0										
NW2	0	0										
SE1	0	0										
SE2	0	0										
SE3	0	0										

Whale Call Data - Page 147

Numbers of Humpback Whales Singing

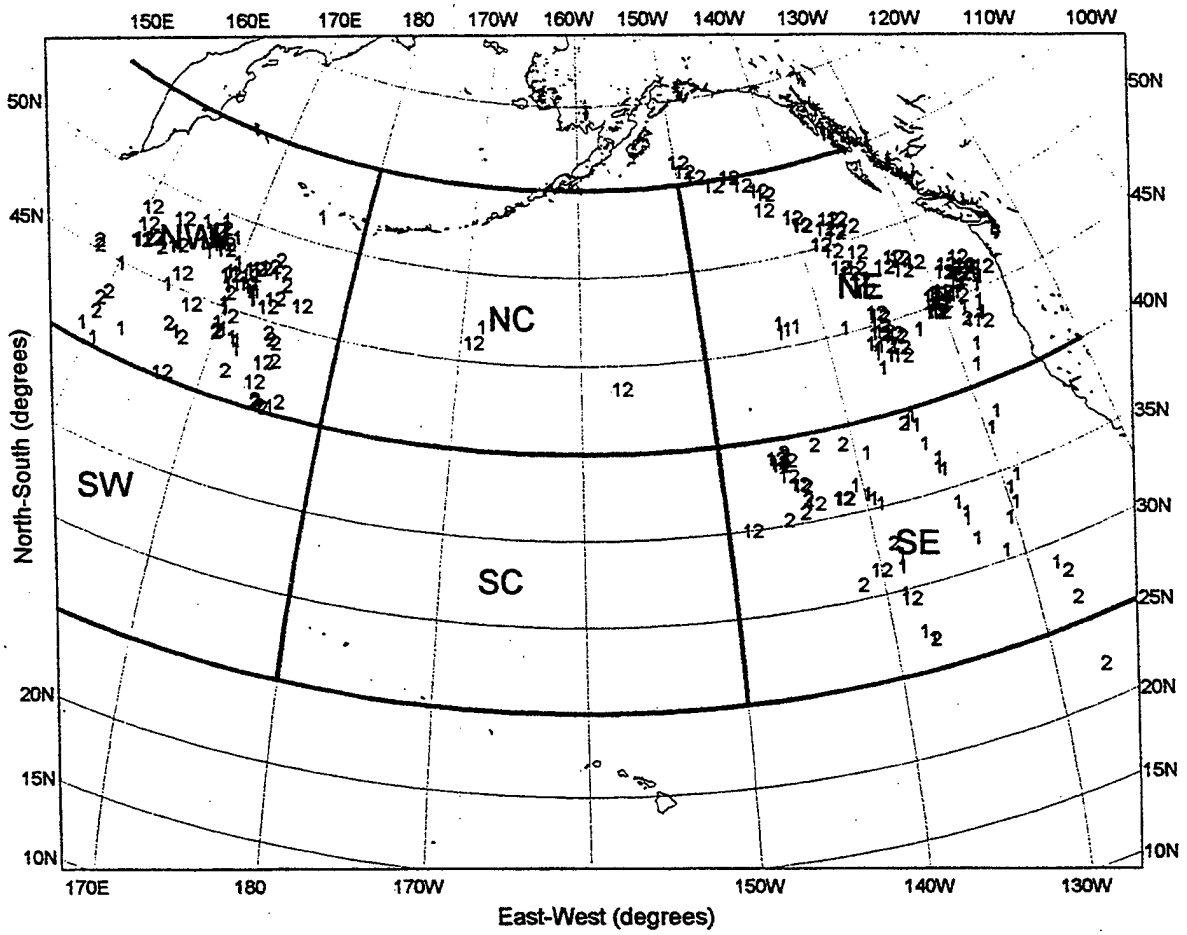
	Jan	Jan	Feb	Feb	Mar	Mar	Apr	Apr	May	May	Jun	Jun
1996	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**
NE1	0	0	0	0	0	0	0	0	0	0	0	0
NE2	0	0	0	0	0	0	0	0	2	6	0	0
NE3	0	0	0	0	0	0	0	0	1	3	0	0
NC1	0	0	1	3	0	0	6	18	61	183	15	45
NC2	0	0	0	0	0	0	0	0	0	0	0	0
NW1	0	0	2	6	0	0	0	0	0	0	0	0
NW2	0	0	0	0	0	0	0	0	0	0	0	0
SE1							1	3	33	99	0	0
SE2							150	450	115	145	0	0
SE3							195	585	151	453	0	0
1997												
NE1	3	9	0	0	0	0	0	0	0	0	0	0
NE2	5	15	0	0	0	0	0	0	0	0	0	0
NE3	2	6	2	6	0	0	0	0	0	0	0	0
NC1	76	228	4	12	1	3	14	42	37	111	8	24
NC2	2	6	3	9	0	0	0	0	0	0	0	0
NW1	1	3	1	3	0	0	0	0	0	0	0	0
NW2	0	0	1	3	0	0	0	0	0	0	0	0
SE1	6	18	1	3	0	0	2	6	6	18	0	0
SE2	100	300	39	117	13	39	95	285	20	60	20	60
SE3	166	498	99	297	12	36	44	132	18	54	0	0
1998												
NE1	0	0	0	0	0	0	0	0	0	0	0	0
NE2	1	3	0	0	0	0	0	0	0	0	0	0
NE3	20	60	0	0	0	0	0	0	0	0	0	0
NC1	83	249	38	114	0	0	1	3	2	6	1	3
NC2	0	0	1	3	0	0	2	6	0	0	0	0
NW1	5	15	0	0	0	0	0	0	0	0	0	0
NW2	4	12	3	9	0	0	0	0	0	0	0	0
SE1	36	108	6	18	0	0	5	15	2	6	0	0
SE2	188	564	79	237	90	270	53	159	1	3	1	3
SE3	177	531	120	360	83	249	12	36	1	3	0	0
1999												
NE1	0	0	0	0	0	0	0	0	0	0	0	0
NE2	0	0	0	0	0	0	0	0	0	0	0	0
NE3	20	60	0	0	0	0	0	0	0	0	0	0
NC1	37	111	5	15	0	0	38	114	40	120	4	12
NC2	9	27	2	6	0	0	2	6	0	0	0	0
NW1	9	27	0	0	0	0	0	0	0	0	0	0
NW2	15	45	0	0	0	0	0	0	0	0	0	0
SE1	35	105	0	0	0	0	0	0	0	0	0	0
SE2	21	63	15	45	7	21	4	12	0	0	0	0
SE3	35	105	45	135	6	18	0	0	2	6	0	0

Whale Call Data - Page 148

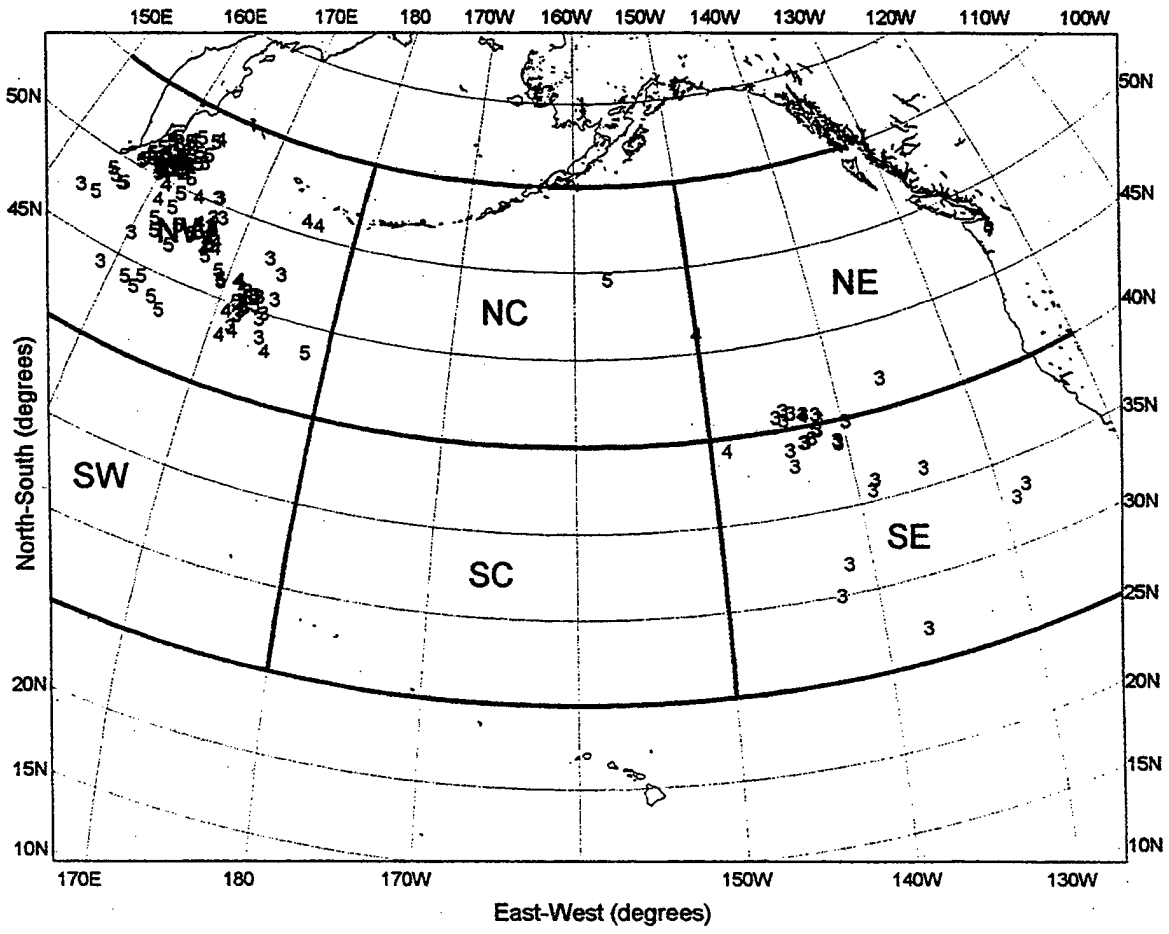
Numbers of Humpback Whales Singing

Jul	Jul	Aug	Aug	Sept	Sept	Oct	Oct	Nov	Nov	Dec	Dec
Actual	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**	**Actual**	**x3**
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1	3	0	0	0	0	0	0	1	3	31	93
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	2	6
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	9	27
0	0	0	0	0	0	0	0	28	84	18	54
1	3	0	0	0	0	0	0	1	3	27	81
0	0	0	0	0	0	0	0	0	0	1	3
0	0	0	0	0	0	0	0	0	0	1	3
0	0	0	0	0	0	0	0	0	0	4	12
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	5	15	13	39
0	0	0	0	0	0	0	0	33	99	20	60
1	3	0	0	0	0	0	0	1	3	25	75
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0										
0	0										
0	0										
1	3										
0	0										
1	3										
1	3										
0	0										
0	0										
0	0										

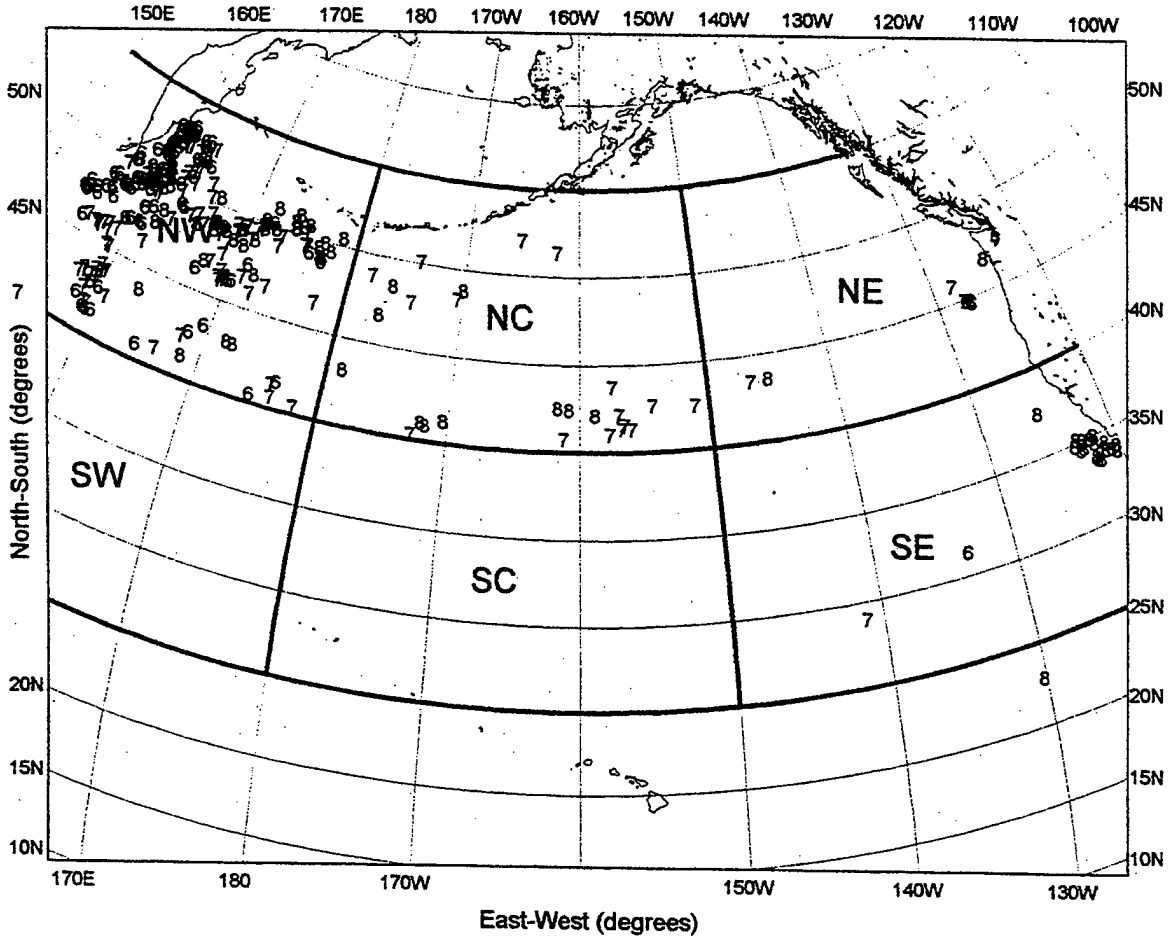
Blue Whale Locations, Winter



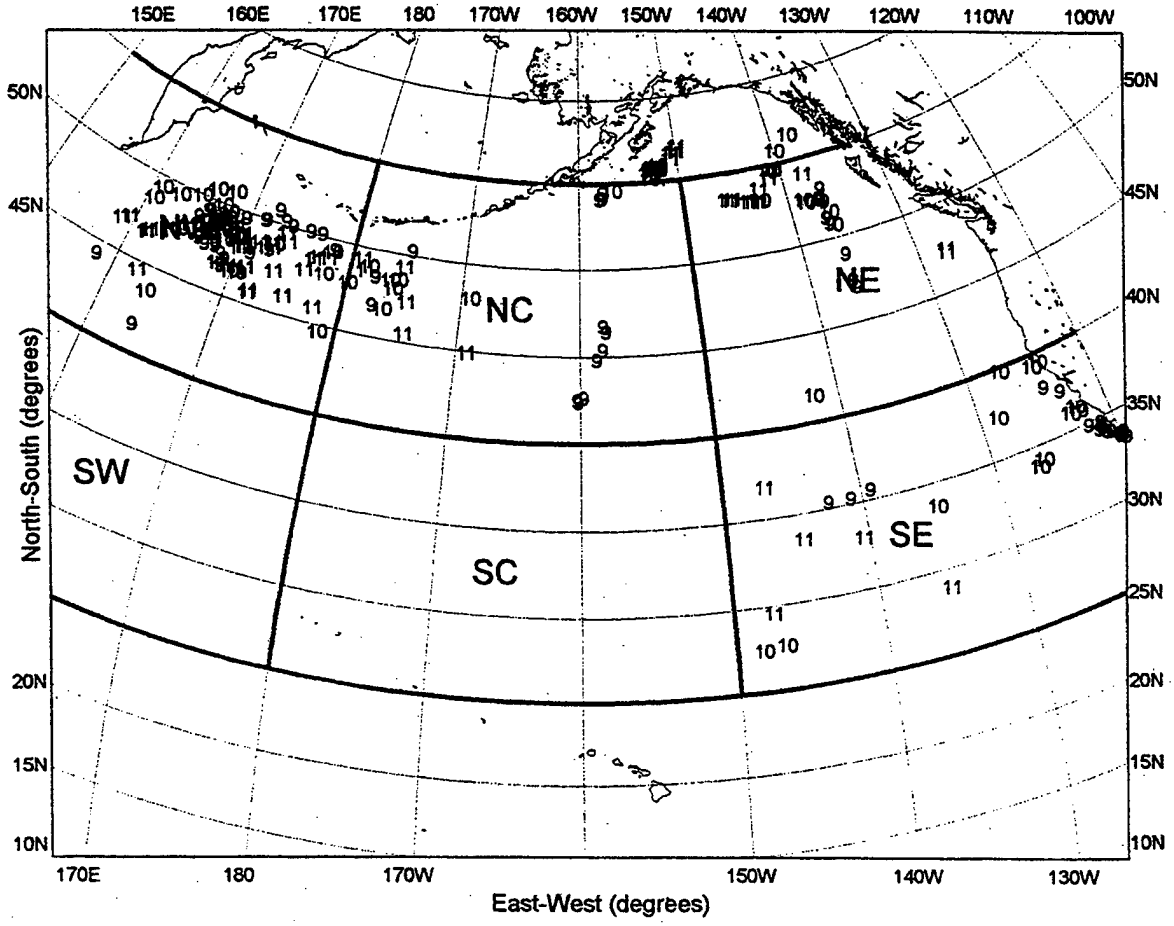
Blue Whale Locations, Spring



Blue Whale Locations, Summer

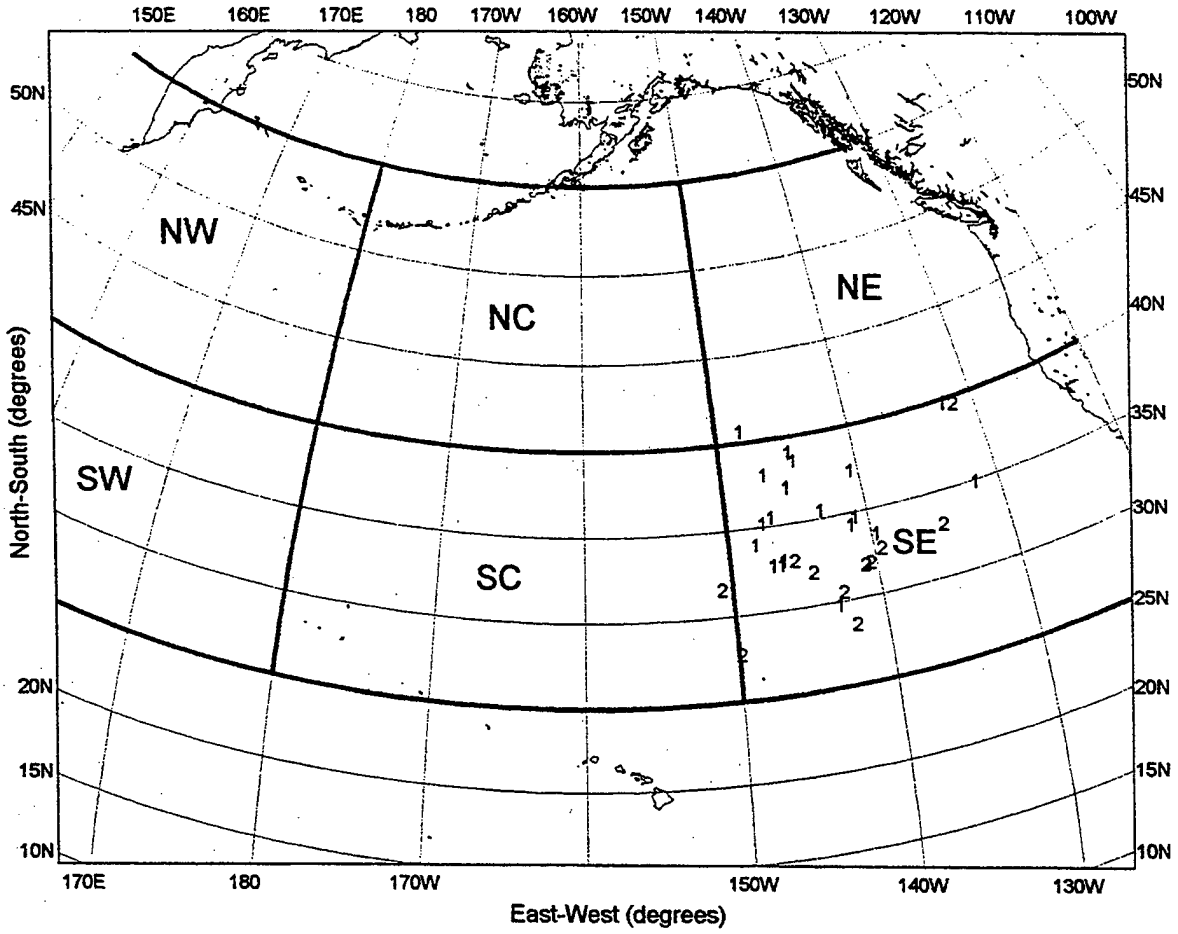


Blue Whale Locations, Fall



Humpback Whale Locations

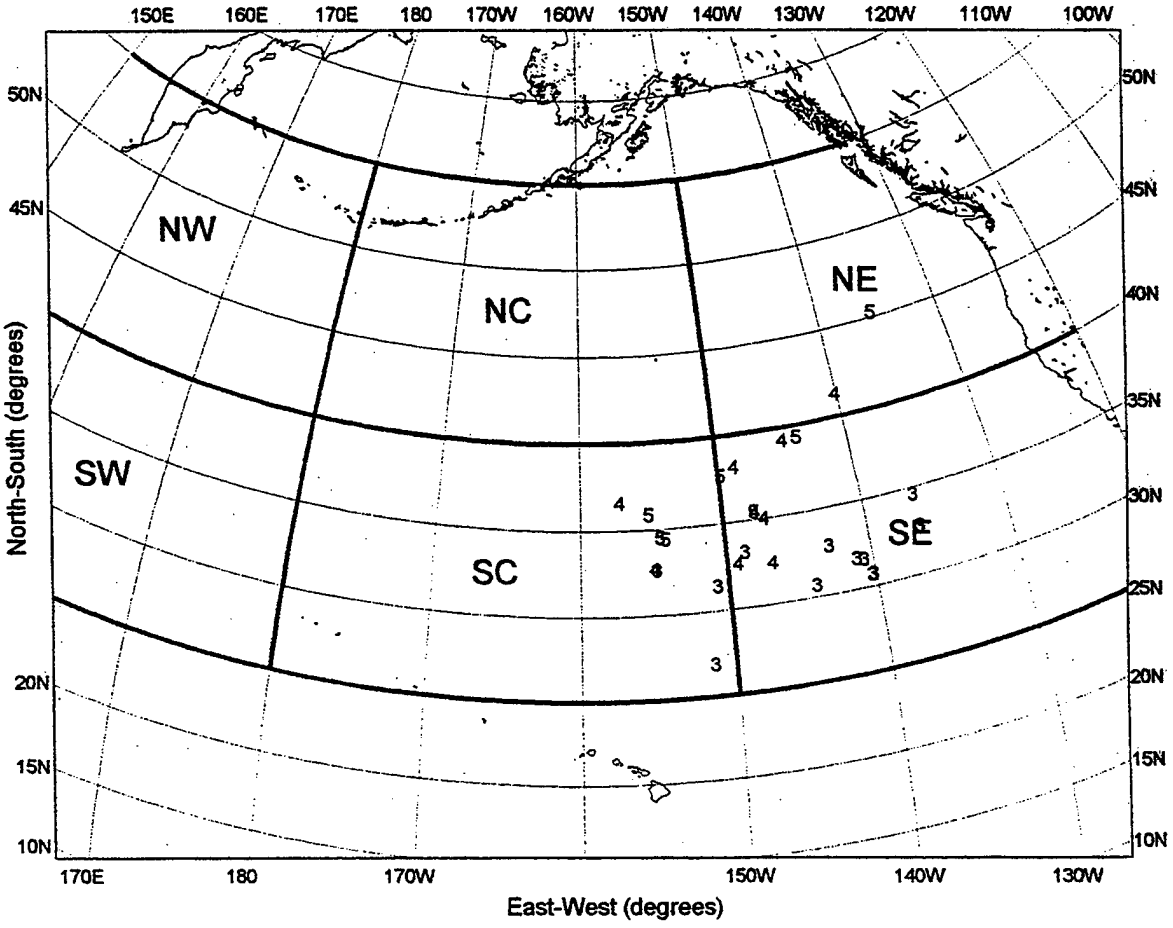
December – February



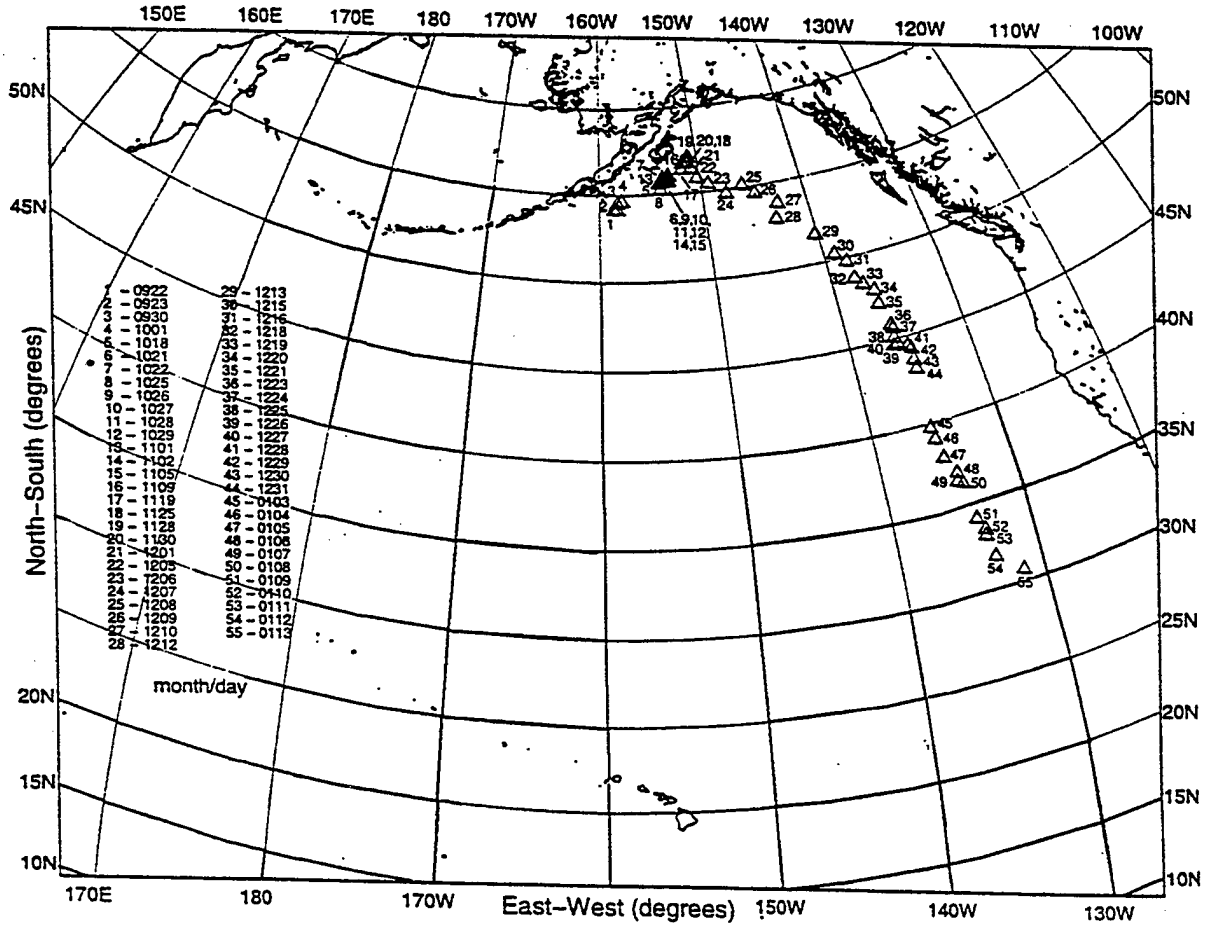
Whale Call Data– Page 154

Humpback Whale Locations

March – May



Track of 52-Hz Whale for 1998-1999



DOCUMENT LIBRARY

Distribution List for Technical Report Exchange – July 1998

University of California, San Diego
SIO Library 0175C
9500 Gilman Drive
La Jolla, CA 92093-0175

Hancock Library of Biology & Oceanography
Alan Hancock Laboratory
University of Southern California
University Park
Los Angeles, CA 90089-0371

Gifts & Exchanges
Library
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS, B2Y 4A2, CANADA

NOAA/EDIS Miami Library Center
4301 Rickenbacker Causeway
Miami, FL 33149

Research Library
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Marine Resources Information Center
Building E38-320
MIT
Cambridge, MA 02139

Library
Lamont-Doherty Geological Observatory
Columbia University
Palisades, NY 10964

Library
Serials Department
Oregon State University
Corvallis, OR 97331

Pell Marine Science Library
University of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882

Working Collection
Texas A&M University
Dept. of Oceanography
College Station, TX 77843

Fisheries-Oceanography Library
151 Oceanography Teaching Bldg.
University of Washington
Seattle, WA 98195

Library
R.S.M.A.S.
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Maury Oceanographic Library
Naval Oceanographic Office
Building 1003 South
1002 Balch Blvd.
Stennis Space Center, MS, 39522-5001

Library
Institute of Ocean Sciences
P.O. Box 6000
Sidney, B.C. V8L 4B2
CANADA

National Oceanographic Library
Southampton Oceanography Centre
European Way
Southampton SO14 3ZH
UK

The Librarian
CSIRO Marine Laboratories
G.P.O. Box 1538
Hobart, Tasmania
AUSTRALIA 7001

Library
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead
Merseyside L43 7 RA
UNITED KINGDOM

IFREMER
Centre de Brest
Service Documentation - Publications
BP 70 29280 PLOUZANE
FRANCE

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. WHOI-00-02	2.	3. Recipient's Accession No.

4. Title and Subtitle
Whale Call Data for the North Pacific- November 1995 through July 1999
Occurrence of Calling Whales and Source Locations
from SOSUS and Other Acoustic Systems

5. Report Date
February 2000

6.

7. Author(s) William A. Watkins, Joseph E. George, Mary Ann Daher, Kristina Mullin, Darel L. Martin, Scott H. Haga, and Nancy A. DiMarzio

8. Performing Organization Rept. No.
WHOI-00-02

9. Performing Organization Name and Address

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C) N00014-96-1-1130
(G)

12. Sponsoring Organization Name and Address

Office of Naval Research

13. Type of Report & Period Covered
Technical Report

14.

15. Supplementary Notes
This report should be cited as: Woods Hole Oceanog. Inst. Tech. Rept., WHOI-00-02.

16. Abstract (Limit: 200 words)

Calls of blue whales *(Balaenoptera musculus)*, fin whales *(Balaenoptera physalus)*, and humpback whales *(Megaptera novaeangliae)* were identified in the data from U.S. Navy Sound Surveillance System (SOSUS) and other hydrophone arrays. These data on calling whales from November 1995 through July 1999 have been listed here for four offshore, deep-water Regions along continental margins of the North and Northeast Pacific. The occurrence of calling whales was monitored during two-day periods each week. Call data recorded from each array identified species, call occurrence, variation, received beam, and relative numbers of calling whales. This allowed assessment of seasonal distribution of calls for the different species, and provided locations for sources received at multiple arrays. Blue whale tonal sounds were distributed widely, received most in the NW Region, with a peak in occurrence in the fall. Fin whale "20-Hz" repetitive pulse sequences were received from whales grouped in local areas in all Regions, with a peak in occurrence in midwinter. Humpback songs were received from December through May particularly in the SE Region. The offshore listening systems allowed basin-wide monitoring of the seasonal distribution of these calling whales.

17. Document Analysis a. Descriptors
N. Pacific Whales
Calling Whales
SOSUS and Whale Calls

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement
Approved for public release; distribution unlimited.

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)

21. No. of Pages
160

22. Price

(See ANSI-Z39.18) *See Instructions on Reverse*

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce